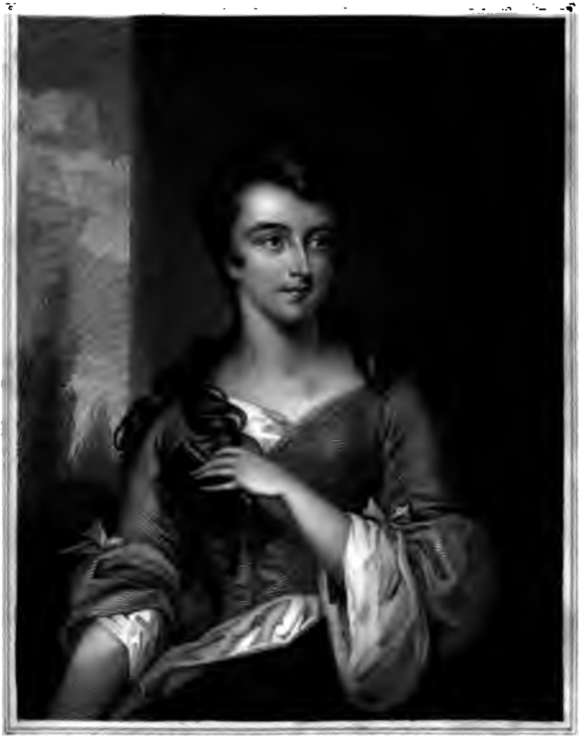
John Bouch.

Wesley



Mrs Susanna Wesley.

A COMPENDIUM

OF

NATURAL PHILOSOPHY,

BEING

A SURVEY OF THE WISDOM OF GOD IN THE CREATION;

BY JOHN WESLEY, A.M.

A NEW EDITION,

REVISED, CORRECTED, AND ADAPTED TO THE PRESENT STATE OF SCIENCE,

BY ROBERT MUDIE;

AUTHOR OF "A GUIDE TO THE OBSERVATION OF NATURE," ETC.

In Three Volumes.

VOL. III.

INANIMATE NATURE.

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PREFACE

TO THE

THIRD VOLUME.

IN this volume I have endeavoured to give as clear and as comprehensive a view as possible of the whole of inanimate nature, in both its departments, the vegetable and the mineral kingdoms. The last of these words, though almost the only popular one that we possess as expressive of matter which is neither animal nor vegetable, is by no means an adequate one; because it ought to include the heavenly bodies, which there seems some inconsistency in designating as minerals. Even then, however, there is less impropriety of expression than might at first sight be supposed; for excepting the trifling knowledge which we have of *the earth near its surface*, by nature and by mining,

the knowledge which we have of the earth is precisely of the same kind as that which we have of the heavenly bodies. We know its size, its quantity of matter, and its motions, and that is the sum of what we know concerning it.

I have found it necessary to deviate still farther from Mr. Wesley's original plan than I did in the former volumes. The reason is obvious; and had the original author lived at the present time, he would have no doubt adopted in substance the views which I have taken. When he wrote, botany, and the various sciences which treat of the mineral kingdom, including the atmospheric air and the waters, had taken no definite form, and no principle was clearly established in any of them. There was also a want of that connexion between science and science which has been traced in more modern times; and which shows in a more beautiful manner than any science singly can show it, the mutual dependence which the whole works of creation, even to the most distant heavenly body of which any precise knowledge can be obtained, have upon each other. This connexion is the very corner-stone of natural theology,—of that feeling of the wisdom, power, and goodness of the Almighty, which is at once the wisest and the most delightful that can be implanted in the human heart; for if mankind are once brought sincerely *and habitually to* feel that God is ever present, and

that his goodness, his might, and his majesty are infinite, they are in a better condition for obeying the laws both of God and man than they are under any other circumstances.

For this reason I have endeavoured to keep the grand consideration of the Author of nature constantly before the reader; not in the obtrusive words of a set and formal phraseology, which but too frequently sound in the ear and pass away without ever touching the heart; but I have endeavoured, with what success is not for me to decide, to translate into our common tongue a few of those sublime and heart-stirring passages which Nature speaks with its thousand voices; and if I have succeeded in this, so far even as to persuade a few to pause amid the vanities of human occupation, and look and listen to the voice of Nature as it tells the wonderful power and goodness of God, I shall feel that my labour has not been vain.

In a small volume embracing so many subjects, one is constantly in danger of stumbling upon that fatality which turns our efforts to be short into steps toward being incomprehensible. "*Dum brevis esse laboro, obscurus fio,*" is indeed a complaint or a confession which ought frequently to be made in these days of abridging. I have sought to avoid the necessity of it by taking an opposite course, making the subjects outstretch and overtop *the words as* much as possible, and then, as for the

latter, I have taken the first and simplest that came in my way. In all the three volumes, but especially in this third one, there is much that is altogether new, at least in the mode of viewing the subjects. On this account I cannot expect altogether to escape the censure of the critics, who, almost officially, must dislike the thing they do not very well understand. The candid will, however, I trust read again.

ROBERT MUDIE.

Grove Cottage, Chelsea,
July 30, 1836.

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A COMPENDIUM

OF

NATURAL PHILOSOPHY.

PART THE THIRD.

INANIMATE NATURE.

CHAPTER I.

GENERAL REMARKS.

ALTHOUGH the study of those works of the Creator which are endowed with animal life, comes most home to the heart of man, and turns his thoughts most toward the great concern of self-knowledge, and self-examination; yet nowhere has the Almighty left himself without proofs of his wisdom and goodness, so clear and legible, that he who runs may read, and so impressive and delightful, that he who reads cannot fail to admire and adore.

The created subjects which come under the cognisance of our senses, and are calculated to exercise our minds and increase our knowledge, but are not possessed of that faculty of sensation *which, whether it* has particular organs allot-*ted to the exercise* of the particular departments

of it or not, is the grand characteristic of animated beings, are conveniently arranged into two great divisions: The vegetable kingdom,—all that grows, and reproduces its kind, and dies, but which does not possess sensation and perception, or those motions in change of place which are the results of sensation—or as we say, though not very correctly, are voluntary, or dependent on the will of the creature—constitutes one of those great divisions; and for various reasons, afterwards to be explained, they are more open to our study, and in many respects more inviting than even the animals. The second grand division comprehends all which is palpable to the senses, and possessed of neither life nor growth, over which death, in the common sense of the word, has no power, and which is not endowed with the faculty of reproducing its kind. There is no very appropriate name in the English language for this grand division. It is usually styled the mineral kingdom; but the name does not apply very happily to the whole. A "mineral" literally and properly signifies "that which is dug up or dug out;" and in this sense it cannot be correctly applied to those substances void of life and growth, which form the upper surface of the bare parts of the earth; much less can it be applied to those ocean waters which cover full seven-tenths of the surface of our globe, and still less yet can it be applied to the atmospheric fluid which, surrounding our earth on all sides, and palpable to light at a very considerable elevation, fines off into the regions of space, until it is impossible to assign its boundary. To this latter kingdom, in its most enlarged sense, belong, not only all bodies which *are without life* and growth, and consequently,

without organisation—inasmuch as organisation is always the consequence, or the work, so to speak, of a principle of growth—but also the substance of every vegetable and every animal, in all their parts and in all their organisations. It is, as it were, the general name of that out of which all things are made which have been made, or shall be made, either by the workings of nature, through the laws and functions which God has given; or the workings of man, according to the imaginations of that spirit which God has given him, posterior to the grand creation, when the Almighty power commanded this matter to arise out of nothing, and gave dominion over it to life and growth, and all the other instruments of His good pleasure.

The study of either, or of both of these divisions of inanimate nature, does not, as we have said, come home to our hearts and feelings, in the way of self-examination and self-knowledge, as that of the animals. But still it is not, on this account, the less fraught with instruction, or the less conducive to the improvement of those means by which we are rendered comfortable in our condition, and by being so, are, or at all events ought to be, the more disposed to express our gratitude to the bountiful Giver of all that we enjoy.

If we endeavour to contrast the two departments, the vegetable and the mineral—or as we might more correctly term it, the inorganic, or rather, the inorganising, for it is in the capacity of forming the organ that the distinction lies—if we endeavour to institute a comparison between these, it is impossible for us to say which of them is the most useful. *From the vegetable kingdom we obtain bread, the staff of life*; and, in addition to this, an

endless variety of vegetables of the most wholesome description, fruits of the most delicious flavour, and wines and juices of various kinds, which are cheering to the heart at all times, and especially fitted for restoring the tone of the exhausted body when we are fatigued, or moistening and refreshing the parched lip, when we are stretched on the bed of sickness. In addition to this, the vegetable world finds us in some of the most cleanly and comfortable, and by far the cheapest articles of our clothing. Fine linen is used in the sacred volume as an emblematical expression of the purity of holiness in those who have been washed from their sins in the blood of the Lamb; and from time immemorial, the cotton tree has supplied from the soft down contained in its seed pods clothing for more than half the inhabitants of the earth. And in modern times, since men began to understand the relations of the different kingdoms and productions of nature, so as to make them co-operate with each other for benefit and blessing, this same cotton plant has been rendered one of the most valuable enjoyments of almost every nation under the canopy of heaven. Considering the beauty of the fabrics into which it is woven, the cost at which they can be obtained, in the smallest quantity, and in the remotest part of any country, where the arts and intercourse of civilisation are carried on, is almost nothing; and it shows how well the works of God are worthy of our study, beyond the mere impulse of momentary appetite, and how grateful we ought to be to those to whom He has given wisdom and understanding to prosecute that study, and bring it to the practical good; that while the price, whether in money or in labour, of every commodity, which from its

nature or from accidental circumstances, has remained in the rude state, or not been animated by the mysterious touch of science, has been increased many fold, the price of this article and of every other to which scientific attention has been turned in a proper manner, has been greatly diminished. And it is no exaggeration to say, that a piece of cotton goods may now be purchased for pence, which would have cost double the number of shillings at the time when the first edition of this work was offered to the public.

It is unnecessary to adduce any other particular instance of the usefulness of vegetables in the domestic economy of the human race; for any one who has eyes, and will use them in looking around him, will perceive how very much of the materials of our habitations, our furniture, the implements of our arts, and, in fact, all our accommodations, are formed of vegetable matter. But we cannot pass unnoticed the ship, by means of which man is enabled to turn the wide-rolling ocean into the safest, the shortest, and the most convenient pathway by which nation can communicate with nation; and civilisation can be spread, and divine truth propagated, and the condition of man improved in every longitude and in every zone. The pine and the oak are goodly trees while they stand towering in the forest, and witness successive generations of the human race passing under their shade, or admiring their grandeur; but when the oak is moulded into the vessel, and the pine erected as the mast, with the rind of the hemp plant twisted into cordage, and expanded into sails, and the ship is properly found in all her appointments, and duly manned by those who have wisdom to

understand and spirit to endure the workings of the deep, and when she is launched upon the wave, and the wind is fair, and the sail is full, and she

"Walks the waters like a thing of life,"

it is impossible to set before the human mind, drawn from the whole empire of material nature, a more glorious sight, or one which displays more in union the bounty of the Creator and the blessing of skill and industry in the creature. Nor must we overlook the curious circumstances by which the pathway of the ship upon the trackless bosom of the waters is rendered as certain as though it were included between walls of adamant too lofty for being overlooked. There is an energy in the globe—in all probability an emanation of that sun which, under God, is the great benefactor, not only of the earth but of a whole system of earths; and yet, like his Maker, does not overlook the smallest creature which is perfectly inscrutable to our senses and our instruments,—there is an energy in the globe which acts in the cross direction to that on which the solar influence falls, and holds nearly a medium distance, in respect of the time which the sun tarries in his apparent declinations. This has its situation in the polar zone, upon which the action of the sun alternates, not merely in light and darkness making up the twenty-four hours between them, but in light and darkness which in the summer and winter alternate with each other in periods of duration longer than twenty-four hours in proportion as the place is nearer the pole, or termination of the axis or line around which the volume of the earth revolves. This energy is technically known by the name of magnetism; and

like all the other general energies of nature, it acts differently upon substances of different kinds; though it is concentrated towards certain poles or points, which vary in their positions, according to laws, the investigation of which is by no means an easy matter. This magnetic energy takes up its abode, as it were, in certain substances, and not in others, just as the energy of heat, or, as we call it, of fire, takes up its abode in fuel, and not in those substances which cannot supply the waste of combustion, or as the energy of vegetable growth takes up its abode in a seed, or that of animal life in an egg; though to the observation of our senses, if we met with the egg or the seed for the first time, we could never imagine that the one would become winged and feathered, and cleave through the sky with the fleetness of the wind, or that the other could be launched upon the waters, as the means of conveying man and his possessions to the most distant parts of the continent and the remotest isles of the sea.

We are so familiar with the production of the bird from the egg, and the plant from the seed, that we are never in any doubt about inferring the one from the other: but this is not an original discovery of the event from the antecedent, at which we could arrive by any process of reasoning, however ingenious, or however profound; and, therefore, when we come to examine the working of those powers wherewith the Almighty has seen meet to endow matter which is not organic or living, we must be careful to keep this analogy of our experience within due bounds, lest it should turn *our philosophy* into error, and our veneration *into superstition*.

All those energies, that of animal life, even in those creatures in which it is capable of the highest development, in respect both of organisation and of sensation, are capable of lying dormant, or at all events escaping from beyond our powers of observation, which to us is exactly the same; and, therefore, we must never in any one case put an absolute negative upon their existence; although their working appears to us only in some cases, and not in others. Thus, when we say that any energy, as that of magnetism or of heat, resides in one kind of substance and not in another, all that we mean, or can mean is, that we are able to observe it in the one and not in the other.

Certain ores of iron display the magnetic energy; and it is also possible to impart it to a prepared piece of iron or steel; and when the iron or steel thus prepared and properly fashioned, is suspended on a centre, so that it can turn freely, it instantly obeys the magnetic energy of the earth, and points to the pole of that energy with the most unerring certainty. This prepared iron or steel so pointed, forms the needle of the mariner's compass; and as it points to a particular spot on the earth's surface, which can be found, it always affords the mariner the means of knowing the direction in which he steers. Nor is it to the mariner alone that it is useful; for it is equally serviceable to the land traveller in the tangled forest where no path can be seen, and on the extended desert where there is no object to guide the eye.

It is true that corrections are required in the use of this wonderful instrument; but the necessity of these is a beauty of it and not a blemish. And it is *one of the most* wonderful adaptations of every

principle and every production of nature to man as a teachable being, and a being whose first duty it is to learn, that there is always enough to reward the study and the labour of the wisest head and the most dexterous hand. Even in those matters where the progress of improvement has been more astonishing, such as that of the steam ship, in which, by means of those energies which have existed since the creation, but which had slumbered till within these few years, man goes forth armed with a bushel of coals and a pitcher of water, in order to stem the current of the most proudly sweeping river, or triumphantly to breast the ocean surges in the very teeth of the gale. In the days when our great grandfathers were young, when science and the arts had not striken hands in that wonderful brotherhood which has been productive of so many benefits to man, the bare mention of the possibility of this, to say nothing of its actual accomplishment, would have been spurned as the mere raving of one whose understanding the Almighty had seen meet to suspend, or to take away. But this has been done; and now that it is done, it appears just as simple as the pulling of an apple from a tree planted by nature, or the breathing of the air by means of those lungs which work without any volition or even knowledge on our part.

This is but one out of a countless number of happy effects which have resulted from the study of inanimate nature; and every department of that nature which has been studied, bears, in as far as knowledge is concerned, no inconsiderable resemblance to *the mind which* knows. As the mind increases *in knowledge it* increases in the capacity of receiving

knowledge ; and whatever the subject is, if the previous acquirements have been of the proper kind, and sought and obtained in a proper manner, the acquisition of new knowledge, of whatever subject it may be, is thereby rendered the more easy; while the very familiarity with a great number of subjects, and the disposition which the mind has, if regularly disciplined, of comparing all the subjects which it knows, and making those comparisons the seeds of discovery and invention, the more that a man knows, he has the greater certainty of increasing the sum of knowledge to the world, and thus being honourably useful in his day and generation.

But in order to attain this high character, this noblest name which man can earn, as connected with this world, no partial view must be taken. We must not in our thinking, as we are obliged to do in our working, take an election of a particular subject; for though division is one of the elements of the improvement of labour, union is the corresponding element of the advancement of thought.

Hence, if we are to look upon inanimate nature either with a view to pleasure or to profit in any other way than as a mere trade or profession, in the exercise of which we are to earn our daily bread, we must look at all the principal departments of it; and we must not look at them singly, and in themselves as subjects of wonder, however wonderful they may be, but must look at them in their relations to each other, as coexistent in space; and we must also look at the successions of their phenomena in the order of time, so as to get hold of the sequence of effect from cause in each of them; and thus turn them all into lessons of expe-

ence, ready for use upon all occasions, in such a anner as that we can infer or predict the occurrence of the effect from the cause, or judge of the ature of the cause from that of the effect.

This alone is true wisdom in the study of nature; nd it has a strong recommendation to us, if, as we ught always to do, we seek in the knowledge of ature the knowledge of nature's Author. We ndeavoured to show in the first volume of this dition of the work, that there are two distinct ranches of creation, independently of the human oul, and the other thinking existence, to which it impossible for us to impute any material princies or properties without falling into nonsense and bsurdity. The one of these is matter, more or ss palpable to the senses, according to the quanty of it, and the state in which it exists, and palpae to the senses as substantive, or occupying space, owever large or however small, which no other atter than itself can occupy at the same instant. The other being action, of which, as substantive, ur senses can take no cognisance; and which is nown to us only by the changes that it produces n substantive matter or that which is palpable to he senses. As this action, however it may be nodified, and in whatsoever it may be displayed, cannot be considered as in itself occupying any portion of space in addition to that occupied by the substantive matter of those subjects in which it is displayed, we cannot attribute properties to action in any manner similar to that in which we attribute them to substance.

Hence action is the wonderful part of creation; and if all *which the* world contains were fixed in *death immutably*, we need not say that it would

be entirely valueless, a creation of utter gloom, about which the mind of no man could bear to reflect. Such being the case, we come a step nearer our Creator, as it were, in the study of action, than in the study of matter considered merely as such, and without any reference to action. It is true that our distance is still immeasurably great; but it is not the less true that this is one step in the advancement; and after it we have only another to take—the communion of our immortal spirits with our Maker in the exercise of religion, natural or revealed. And though this is totally different from our contemplation of action in matter, and has its grand bearing upon our condition in a future and immortal state of existence, yet it is a step of advancement toward this learning for immortality, which we never could take if we chained down our reasonings to matter as substance, and to those appearances and properties of it which are palpable to the senses.

If the illustration by a similitude is admissible, and there does not appear to be any impropriety or inaptitude in it, we would say that, between the study of mere substantive matter in the material creation and the study of action in the same, there is very nearly the same difference that there is between the worship of the dumb idol in religion and the worship of the true God. The God of Nature and of Revelation is THE LIVING GOD; and, therefore, we must both seek to know Him and labour to do Him reverence in that which is endowed with life; and, we may add with perfect *truth, that* those natural religionists who study the *works of* nature as mere matter, without studying *their working* as produced by action, are really

idolaters in this matter, whether they themselves happen to be aware of it or not.

Such is the spirit in which it behoves us to come to the study of nature; and when we come to it in this spirit, and conduct our observations and comparisons in a proper manner, and with constant regard to the truth, and the truth only, this study is not only much less difficult than from the number and variety of subjects to be studied we should be led to suppose, but there is no difficulty in it at all, and it becomes at once the easiest and the most pleasing occupation in which we can be engaged.

We must have some method of proceeding where matters are presented to us in a way so very miscellaneous: and in all cases where we wish for sound knowledge, the short and the safe plan is to begin with the most general view that can be given, and work downward by analysis to the particulars; because in this way, the knowledge which we acquire is of general application as far as it goes, and we can take it up and pursue it more in detail, according as necessities require or subjects present themselves to our contemplation. Whereas, if we took the opposite method and began with the details of particular subjects, those details would be but of small use to us in the study of other subjects. Nature is a complete whole; and the first view we take of it ought to be taken as of a whole. Before this can be done, however, it requires that very considerable progress should be made; for though this is the way in which the truths which have been established are soonest and most easily learned, *yet it is not* exactly the way in which *primary truths or facts* dependent upon observation

are at first acquired; and thus the labours of the student who seeks existing knowledge, and of the professional man of science who seeks to increase the quantity by original observation, are different in kind; or, which comes nearly to the same thing in effect, different in the mode of conducting them. At the time when Mr. Wesley studied, and even at that when he prepared his compendium of the Philosophy of Nature for the press, the science of generalisation was in its infancy; and, therefore, many parts of his book, whether original, as from himself, or copied from those writers from whom, as he himself confesses, he copied the greater part, are disjointed, and consist of fragments, and sometimes of repetitions which, though often of much value and interest as particulars, can hardly be used as instruments of general knowledge. Very many parts, too, in his time were conjectural, respecting which most, if not all, of the conjectures, as usually happens in such cases, were inaccurate; and on this account, though without any blame on his part, the scientific value of the book, especially in the latter part of the second and in the third and fourth volumes, bears but a small proportion to the quantity of reading. Accordingly, an attempt is made in the present volume to condense and generalise these matters, and free them from repetition, in order that the book may be more useful to the general reader, by being a brief index to the works which contain the details, instead of detached specimens of even the best parts of a few of them. In this view of the method of treating the subject, some clearness, and, therefore, some practical advantage to the reader, may be obtained by considering in succession the following general heads:

First, the Vegetable Kingdom, or those productions of nature which form the covering of the earth, and which, next to animals, have most of the principle of action in themselves; and, in consequence of this, have the power of assimilating other matters to their own substance, and thus increasing in size by growth.

Secondly, the Mineral Kingdom, in its more correct and limited sense, as it includes those inorganic matters which form the solid part of the globe. In this division, the individual substance is wholly subject to the laws of inorganic matter, without any power of assimilation or of growth, and, consequently, without any organs for the performance of specific functions. But still, the very solidity which those matters possess, though it is a state out of which most of them have been changed, and all of them probably could be changed, shows, that they, to a certain extent, possess some property, or obey some law, by means of which they, within certain limits at least, can retain permanency in their forms.

Thirdly, Fluids, of which, the principal ones that present themselves to us, in the observation and study of nature, without the performance of any experiment, a species of operation which is altogether incompatible both with the size and the plan of this work, are, water and atmospheric air. There is a distinction between these, as to the states in which they exist; the water being a liquid, or palpable to the senses, and capable of assuming a separate form in detached portions, when circumstances favour such an assumption—as may be observed in dew-drops on the leaves, and still more remarkably in those beautiful little spheres, or globules of water,

which shower down from the clouds, or danc along the surface of water itself, from the dash a waterfall, the breaking of a wave, or the rippl of an oar. The atmospheric air has no such pro perty as this; and there are no circumstances i which we can observe a portion of it possessing definite shape, unless it is confined in a vessel some description or other.

These properties do not belong to the water an the air in consequence of the nature of those sub stances, as dependent on the parts of which the are composed, and on the way in which those part modify the properties of each other, or produce ne ones, in consequence of the proportions in whic they are mixed together: they belong to the state and every substance, whatever may be its natu or its use, which we can call a liquid, partakes the general property of liquidity, as we find displayed in water, though this property differs degree in liquids of different natures. In lik manner, that aëriform, or gaseous state, which the distinguishing character between water and ai is common to every substance which exists in state which is neither solid nor liquid. But as tho three states are exchangeable with each other, bot by many operations in nature, and by many pr cesses in the arts, it is to be understood, that wh we speak of inorganic matter as solid, or liqui or gaseous, we do not speak of three kinds matter, or even of any one kind of matter as regar its other qualities, but merely of the particular sta in which matter exists, and this state is part *dependent* on the kind of matter itself, and part *on the* degree of action to the influence of whi *it is subjected.*

The three divisions, of which we have now given brief definitions, comprise the whole inorganic portion of the solid earth, the sea, and the surrounding atmosphere, together with the matter of which all organised beings are composed. But when we turn our view to the apparent canopy of heaven, over us, and behold the splendour of the sun, the beauty of the moon, and the sparkling glories of the starry sky, we find it so impossible to limit our desire of knowledge to the earth, and what the earth contains, that those heavenly bodies become objects of attention to the infant almost as soon as it is capable of distinguishing from each other those objects with which it is most familiar. Hence,

Fourthly, we shall very briefly survey the Heavenly Bodies as forming the great system of material creation, and the portion of it in which the "still small voice" of the Creator, telling upon man, in the impression on the heart, and not in sound on the external ear, proclaims in the most impressive manner, the boundless extent of the majesty of the Most High; by showing us, that even his material works extend farther than the line can measure, the eye discern, or the mind imagine.

Fifthly, we shall advert to the leading divisions of that action, which is displayed in all the parts of nature, from the germination of the most tiny mould, or the minutest animalcula, to masses of matter careering through space more fleetly than the lightning of heaven, and exceeding our earth in volume by a quantity which to our comprehension is indefinitely great. This action, in whichsoever of its modifications we consider it, is the most important of the whole subject; but it is the one which requires to

be approached with the greatest caution; for while we are constrained to admit, that it is a work, and an essential work, of the Creator, indispensable to the well-being of all His creatures, we must at the same time beware lest we should materialise it; that is, assign to it a separate existence, as capable in itself of being seen by the mortal eye, or rendered palpable to any other sense, whose organ being substantive in itself, can, in the simple or individual act, discern nothing but substantive matter, until it has transferred its impression to the reflecting mind, in that mysterious manner into the nature of which it is not given us to look.

After we have briefly, but as fully as our limits will permit, adverted to these five heads of division in their order, we shall close our observations by a very few general reflections on the whole works of creation, and the leading advantages which we may derive from the careful study of them.

CHAPTER II.

THE VEGETABLE KINGDOM.—DEFINITION, STRUCTURE, AND PRINCIPAL DIVISION.

THE word *vegetable*, and the word *plant*, are often used indiscriminately, as generally expressive of any member of this kingdom of nature, but originally, they have different meanings. The word vegetable properly means that whose distinguishing character, by which it is more immediately discriminated from the other productions of nature, is the property of growing or increasing in size from a germ; but in the vegetable as well as the animal,

this germ, except in the original act of creation, must be transmitted from a parent; and when we take growing as the proper and predominating character, there is implied in it, that the vegetable has no organs of sense, and no sensations,—that it has nothing in the least degree analogous to a nervous system, or to a muscle; and that, consequently, it is subject to none of the affections, and can perform none of the functions, for the performance of which nervous and muscular systems are required. The word plant, again, means that which is placed or rooted, and maintains a permanent position by means of a portion in or on the surface of the ground, of a rock, or of some other plant or solid substance. This last property belongs very generally to the vegetable kingdom; but it does not belong to all vegetables, for there are some, as lemma, or duck-weed, which covers ponds and ditches in warm weather, floats in the water without any root in the earth, though it sinks down during the autumnal cold, and remains quiescent in the mud at the bottom, during the winter. So also, there are plants or vegetables, and some of them very splendid in their flowers, and exceedingly elongated in their stems, which twine round the boughs and the branches of the majestic trees in the tropical forests, and sometimes overtop the most lofty of them, and ornament them with a festooning of the most exquisite blooms, which have no roots fixed in the earth, or even in the holes or forks of these trees, but are literally suspended in the air, and thus, not unappropriately, have obtained name of air plants. Still, however, there is no mistaking a plant for a member of any of the other *kingdoms of nature*, provided that it is found entire,

or in its efficient position for affording a display of its proper characters.

There have been successively, in different ages, though in varied modes of expression in each age, opinions broaehed, as to the spontaneous production of the more simply organised vegetables out of inorganic matter, and by faculties inherent in that matter alone, without any germ transmitted from a parent vegetable; but all these are nothing more than the attempts of ignorance to elevate itself into the chair of knowledge, by endeavouring to invent a substitute where it cannot discover a fact.

As plants are constituted, from the very fact of their being placed in fixed situations, or committed to the water—for there is no evidence that any plant floats or can float in the free air, so as to carry on the functions of vegetation there—it is necessary that the germs of them should be endowed with greater powers of endurance than the germs of animals; because, in almost every instance, the parent animal has the instinct of placing the rudiments of its offspring in the most favourable situation for their development and progress to maturity, while the plant merely scatters its germs around the locality in which it is situated. But still the plant is, in this respect, as completely adapted to the circumstances in which it is placed, as is that which we reckon the most provident animal; for the germs of vegetables, generally in the form of seeds, and often of very minute ones, are scattered every where; and it is scarcely possible to turn up any accumulation of mould, or earth containing vegetable matter, however deep it is, how long soever it has lain, without finding every portion of it fully plenished with the *germs of vegetables*; and if an accumulation of this

kind has been formed by successive deposits, in the course of a long period of years, during which the ground which supplied it had undergone considerable changes, then portions brought from different depths furnish crops of different vegetables; and thus the accumulation becomes a kind of rude record of the history of vegetation during the period of its collection. Many of those germs are winged, so that they ride freely on the winds; others are so minute and so light, that they are blown about perfectly invisible; and those which are of too much size and weight for the winds to carry them, are spread abroad by the rains, the rivers, and in many instances even by the ocean itself. Thus there is not a part of the earth adapted for the growth of a vegetable, from which the seeds of vegetables are withheld; and we find that those remote islands of the wide seas, which are brought up to the surface by the labours of the coral worms, and reared a little above by the action of the ocean waters, have no sooner got above the permanent surface of the deep, than they are supplied with vegetables, though no observation can find out their way there. Nor is it in the land alone that we find this exuberant supply of provision for the support of plants; for the sea is scarcely less productive; and though the same kind of structure is not required in a plant supported by the water, that is necessary for one which has to support itself in the free air, yet, to a very considerable depth, the waters are as full of vegetable life as the land is.

But there is the same line of distinction drawn between the land plant and the water plant, as we find *between every* other two departments of *nature; there are,* indeed, on the margins of the

sea, where the tidal waters ebb and flow, numerous plants, which can bear the alternation of being wholly immersed in the water, and wholly exposed to the air; and there are also others whose constant habit it is to grow with one part of their structure in water, and the remaining part of it in the air. Plants of either of those descriptions are, however, plants of peculiar localities, and we never find any of them flourishing in a situation which is either permanently below the water or permanently in the air.

There is one general distinction between the vegetation of the land and the vegetation of the sea, which is well worthy of attention, as showing the close connexion between the vegetable kingdom and what we are accustomed to call the general action of the elements. The water, owing to causes to which we shall advert afterwards, is far more uniform in its temperature than the land; and there is much less light under the water than on the land, because of the portion of it which is reflected from the surface. In agreement with these circumstances of the situation in which they are placed, there is much less diversity both of parts and of colour in the plants of the water than there is in the plants of the land. No plant which grows wholly submerged, whether in the fresh water or in the sea, produces any fibrous substance bearing the least analogy to the woody parts of land plants; and the distinctions of root, stem, and leaf, which present themselves in aquatic vegetation, are mere distinctions of form rather than distinctions of structure. What are usually called the roots of such plants, too, are not organs of *nourishment*, as is the case with the roots of all

plants which grow in the earth, they are mere hold-fasts for retaining the plants in their places; and the whole nourishment of the plant is derived from the water in which it floats. The water of the sea contains a large portion of soda, in combination with muriatic, that is hydrochloric acid, or with sulphuric acid; and a considerable portion of this soda enters into the composition of almost every marine plant, and imparts to such plants a sharpness of taste, and, in many of the species, very agreeable medicinal qualities. But we shall, perhaps, have occasion afterwards, briefly to mention those matters. The marine plants are equally remarkable for the uniformity of their colour, which is generally a dingy brown, with only a faint trace of bronze green; though some of those which are by turns exposed to the sun and air, in consequence of the ebbing of the waters, incline more to green in their colour, and others incline more to red. The green ones are generally more mild in their character, and the red ones more pungent; the greenness being ow ng to a predominance of alkali, and the redness to a predominance of acid. We find differences, though not so decidedly marked as this difference of marine and terrestrial plants, between the plants of different latitudes, different elevations, different exposures to the general currents of the atmospheric fluid and the action of light, and also to different characters of soil and forms of surface, even in localities which, generally speaking, are similarly situated upon the globe. But we shall be better able to understand these in a subsequent part of our brief notice; we shall, therefore, now very shortly notice

The elementary parts and the general struc-

ture of Plants.—The principle of all vegetables are charcoal and water; the charcoal being technically named carbon, which is merely the Latin name for a burning coal, or rather for the cinder or powder—different from that composing any kind of stone, metal, or earth which has never been organised—which is left after the more inflammable or flame-producing parts of fuel have been consumed. The elements of water are oxygen, or that which is the principal ingredient in most substances which have an acid or sour taste; and hydrogen, which, like the other two, enters into the combination of many substances, when it exists separately, or free from admixture in the state of air or gas, is the lightest substance with which we are acquainted. It is also exceedingly inflammable; and though it cannot be burned without the admixture of oxygen, also in the state of gas, yet when the two are combined in the same proportions to each other as they exist in pure water, the combustion, which is, in fact, nothing else than the process by which water is formed, is productive of the most intense heat and the most brilliant light with which we are acquainted; for which reason it is used as a substitute for the direct light of the sun, in solar microscopes for showing transparent or semi-transparent objects, magnified a vast number of times, so that the particulars of them may be much better understood than by the unassisted eye. These three ingredients may be considered as the grand constituent elements of which all the more solid parts of plants are composed; but in addition to them there are various other comparatively simple elements, *and an endless* number of products, some of which

have hitherto set analysis at defiance, so that it is impossible to say whether they are simple or compound. Potass is found in a great number of land plants, in like manner as soda is found in the greater number of marine ones, and of those which grow in the salt marshes. It is highly probable that this potass has a considerable influence in producing the green in vegetables, which, in the leaves of trees, and in the general carpeting of the earth by grasses and other plants of humbler growth is so very refreshing to the eye. Some few plants also contain a portion of silica, or the earth of flints; and this earth occurs in such quantities in the hard rinds of some reeds, that they will strike fire with steel; and sometimes during the very dry seasons in tropical countries, they rub against each other by the action of the winds, and set the forests on fire.

Of the peculiar products which exist ready-formed in the substance of plants, or which can be extracted from them, the varieties and the properties are so many, that the enumeration of them in any way which could be either pleasant or popularly instructive, would fill many volumes. Some of them are deadly poisons; others are wholesome medicines; others again, are nutritious food; and there are still others which are used for dyeing, for tanning leather, and for a vast number of purposes in the arts. One of the most singular of these peculiar products is *caoutchouc*, or, as it is usually termed, Indian rubber. This substance is the juice of the stems of various trees, which grow in the tropical parts both of the east and of the west; and it is not a little singular that, among vegetable *substances, it is* the one which partakes most

largely of nitrogen, or that element of the atmosphere which is passive in the respiration of animals, and probably also in the less understood operation which takes place between living plants and the air, and which forms a constituent part of all substances that are really animal, and imparts to them that odour of ammonia or hartshorn, by which an animal substance, when burned, is in general so readily distinguished from a vegetable one. In some parts of the world, as in South America for instance, more especially in the tropical parts of it toward the Andes, this substance is produced in such abundance, that the natives designate the plant by the not inappropriate name of the cow tree, *palo di vaca;* and they are accustomed to fetch daily from it ample supplies of very delicious milk, or rather cream, not inferior to that which is obtained from dairies in our parts of the world. The number and the variety of those peculiar products of vegetables, and their uses in domestic economy and in the arts, are however, so very great, that we must pass them over, and proceed to notice the structure of vegetable bodies.

Vegetable structure. In the second volume of this work, when treating of animated beings of the most simple organisation, we had occasion to show that the very simplest form of animal life is that in which the whole organisation of the animal is deduced to a sentient membrane, which is also endowed with the power of growth, and with the faculty of reproduction. In the vegetable structure we find only a growing membrane, without sensation, but endowed with the faculty of reproduction, either in the whole membrane, as in those

less developed animals to which allusion has just been made, or restricted to particular local organs, as in the case of those animals which have their faculties more numerous, and their organisation perfect. This, as we shall afterwards see, is the principal means by which we are enabled to classify the members of the vegetable kingdom; for those which reproduce their kind in a similar manner, are similar in most other respects; and, generally speaking, they can be made to hybridise with each other, which is the case with animals, though perhaps to a much less extent. This we might expect; for as the animal has many more resources inherent in itself than the vegetable has, it follows naturally, and, indeed, necessarily, according to a very general law of the creation, that the latter should yield more to external circumstances, whether those circumstances are the results of natural causes, or brought about by the practice of art.

This, by the way, is a very beautiful portion of the economy of nature. We could imagine the vegetable kingdom to exist without the animal kingdom; because, though there are various ways in which animals contribute to the growth, and also to the fertility of vegetables, yet there is no known instance in which a vegetable feeds upon, or is nourished by, the substance of living animals. Without animal manure, the fields of such a country as England would, indeed, yield very scanty crops, either of corn or of grass; but still it is for a kind of vegetation, and not for vegetation generally, that this species of enrichment of the soil is required; and every part of the world, how poor soever, which is without the limit of perpetual frost, and also not overhanging the rock or shifting sand, has

its vegetation; and this vegetation, in some curious species of plants, finds its way even into the darkness of mines and caverns where no ray of the sun, and no gleam of natural twilight ever enters. Now this superior adaptation to circumstances on the part of vegetables, is a great security, not merely to the vegetables themselves, but to the whole growing and living creation. Vegetables are the primary food of all animals, for those species which do not feed directly upon vegetables, make prey of those which do; and thus the great preservative power of vegetables is the grand preservation of the whole. This greater security—which, from its very nature, the supporter has, than that which is supported,—is one of the most striking instances of design which we meet with in the whole range of nature's productions; and though it perhaps appears more conspicuously in the contrast of the vegetable and animal kingdoms than it does any where else, yet we find the same bountiful provision running through the whole system—that which is consumed being always more secure and more abundant than the consumer. It is in this wonderful provision for every creature which pervades nature in all its departments, that we find the most impressive manifestation of the infinite goodness of the Creator; and it is also a beautiful part of the system, and one which is fraught with great practical instruction, that simplicity in the organisation of every thing which grows or lives, is in itself a means of preservation against those casualties (at least casualties to our limited view, for with God there is no casualty,) to which, in a system consisting of so many parts, each part must be liable. *This strongly* impresses upon us, that if we are

safe from casualties, whether as affects our
lth, our lives, or our worldly prosperity, we also
st be simple; and thus the whole creation, while
sets before us means of enjoyment which are
most unlimited in number, and varied so as to
; every taste, becomes to us one grand lesson
temperance in the use of all that it affords,—
the austerity of the anchorite, which abstains
proud supererogation from the good which the
mighty has given, but the thankfulness which
epts and enjoys His bounty in moderation and
h gratitude.

The elementary structure of every vegetable is
membrane, and this membrane, in the living
nt or in the germ, is always filled with a sub-
nce more or less fluid, or capable of being ren-
ed fluid by the requisite application of heat and
isture. When this membrane consists of a
ies of little sacs or vesicles, the texture of the
nt is said to be cellular, that is, composed of
le cells or cavities. Those cells differ greatly
m each other, both in size and in shape, in dif-
ent plants, and also in the same plant in different
ges of its growth, and in different parts of its
icture; but still it is in all cases to be under-
od that the containing cell is the working struc-
e, or that portion of the plant which is really
anised; and that the liquid contained in the cell
ither pabulum or food, that is, the material out
which the membrane of the cell is to elaborate
r matter, or a product of organisation, not in
lf organised, as is the case with all the gums
l resins, and those other peculiar products to
ich we have already alluded. The walls or
mbranes of their cells are often exceedingly

thin, and the cells themselves very minute. many plants, indeed, they get beyond the powe dissection and the scrutiny of the microscope; in every plant which we can examine, the i vidual cell is always entire, except when broke external injury; and how closely soever they be compacted in the cellular substance, the p tions between them are always double, so that one has no perceptible communication with other. As long as these cells remain active performing the functions of the plant, they therefore, to be considered something in the l of a vast number of little stomachs as it w which are mouth all over, and capable of absorl the constituent elements of the plant, most pr bly in the state of gas, and divided down to ultimate atom; and that which is thus absorbe afterwards combined into the necessary compc by a curious process of assimilation; and ther a manner equally mysterious, it is given out by cell, prepared for those new formations which plant exhibits. We shall afterwards, however, l to advert to this very interesting part of the sul when we come to notice the life and growth of pla

Besides those cells, and the cellular subst which they compose, there are many plants w have other organic structures, independentl those external parts which are visible to the ey an ordinary observer, without any dissection dividing of the parts of the plants. These co of vessels or tubes of various forms; and it i the number and perfection of those tubes that superior organisation of one plant above ano consists. The cellular substance is, however, i cases, the primary structure, and the one by w

the vascular substance is at first elaborated; and we find in this a remarkable analogy to what takes place in the development of an animal, for the primary embryo there, in all cases in which we can trace it to its most rudimental state, is a simple vesicle or membranous cell, containing a fluid or a substance capable of becoming fluid.

We are therefore to consider, that it is in the cellular substance that the power of increase in all plants reside; and we find some circumstances connected with the display of this power of increase, which show us, very strikingly, how much more a vegetable is obedient to the common laws of matter, than an animal is. If we examine the south side of a tree, upon which the light and heat of the sun act with great power, and then examine the north side of the same tree, under circumstances which prevent it from receiving much of the action of the sun, but which expose it to the chilling wind and nipping frosts of the north, we find that the cellular substance of the south side is far more developed than that of the north side; and that it also continues longer in a state of activity. A common pine is a very favourable tree, in the trunk of which we observe these different effects of different exposures. When the cellular substance of the pine ceases to have any internal action, and becomes compressed by the new layers of wood which annually accumulate over it, it becomes darker in the colour, and contains much more of the turpentine or resinous juice of the timber than that which is still in a state of activity; and in the circumstances which have been mentioned, it will be found that there are more layers of wood which have not *received the red colour* on the south side of the

tree than there are on the north; and that the layers on the south side whether they have or have not received the red colour, are thicker than those on the north; but whether they have or have not received that colour, the southerly ones are softer, and by no means so durable as timber as the others.

This shows us that the part of the tree which enjoys most of the solar action partakes most of the exercise of vegetable life, not only in the greater quantity of matter which is produced, but in the greater length of time during which that matter remains active. All vegetable structures while working are perishable, because the contents of the cells are liquid; and if they are prevented by separation from the rest of the plant, or by any other means from continuing the functions of life, during their appointed time, they either putrify in the same manner as the soft parts of animals do, or they shrivel up by the evaporation of their liquids or juices, as is done by animal matters which are exposed to an atmosphere at once very hot and exceedingly dry.

These considerations, which any reader can very readily extend for himself and confirm by observation on the actual state of plants, suffice to show the very powerful action which the heat and light of the sun have in stimulating, and also in preserving the function of vegetable life; and there are some other circumstances which show that the principle of gravitation has more influence on the original formation of plants than it has on that of animals. It is true that in the greater number of plants, the vegetative power is sufficient to bear up

composing the substance of the vegetable; and to elevate not merely the contained fluid, but the containing cell or vessel; and this is a complete refutation of all those attempts which were made, when mechanical philosophy was predominant, chemistry not understood, and physiology was attempted to be explained on mechanical principles, to show how the different parts of a plant acted like those of a machine,—as, for instance, that the sap in plants, as taken in by the spongelets of the roots, or otherwise, ascended on the principle of capillary attraction, that is, the attraction or tendency toward each other of a wettable tube, and wetting fluid, when the bore of the tube is too small for allowing the mere gravitation or weight of the contained quantity to press it downwards and prevent the ascent. In order to make the case at all parallel, there would have been required a reciprocity of action between the fluid and the capillary tube; that is to say, either alternately or contemporaneously, the tube ought to have elevated the contained fluid, and the contained fluid to have lengthened the tube. This is exactly what is done in every vegetable; and therefore, unless an analogy drawn from mechanical action will explain the whole of it, it cannot be held as explaining any part; for, of the containing cell or vessel, and the fluid which it does contain, we cannot say that either of the two is the stimulnat, and the other the thing stimulated. They work together, and produce a certain specific effect, according to the special character of the vegetable, modified by circumstances; and it is beyond all our powers of analysis to separate them in their working, and to say what portion of the

elementary function depends upon the one, or upon the other.

But, though in this we have a clear and convincing proof that the principle of growth by which vegetable structures are elaborated and organised from inorganic, and, as it should seem, gaseous materials, we still find that the power of gravitation has an influence in the primary operation of vegetable growth.

We might, indeed, have inferred this from the general analogy; because there can be no action, whether of life, of growth, or of any thing else, without a corresponding resistance. The active principle must, indeed, be stronger than the resistance, otherwise it would not overcome that resistance; but still, whatever the strength of the active principle is, the force of resistance is always an element in the effect. We have many illustrations of this, in the case of animals. Man, for instance, can walk on, or can leap from, the surface of the ground, but he neither can walk on the water, nor leap from it; although the strength of the same man must be the same, whether he is upon land or in the water. In like manner, none of the mammalia, or the reptiles, unless such as are furnished with flying membranes, and with pectoral muscles something analogous to those of birds, can take any sort of leap, or in any way renew their motion, while in the air. Some persons, indeed, who display their muscular powers to the wonder of the vulgar, in order thereby to earn their daily bread in what is perhaps not the most commendable use of the powers of the human body, can alter the position of their bodies, or turn them round,

during a leap, and even assume the appearance of taking a second leap in the air; but all this is mere practice, and they do not advance a single hair-breadth beyond the strength of the impetus which they received in springing from a solid support; the elasticity of which is often made use of as a supplementary aid to the muscular force of the leaper.

Now, if it is asked, why such animated beings, whatever may be their strength and agility, cannot perform in one element those simple acts which they can readily do when they begin from another, the answer is, that there is not sufficient resistance; and this shows that resistance is always an element of action, and that though the active power belongs to the agent, yet the resistance is always a measure which the action cannot exceed.

It is especially necessary to bear this in mind, when we study the action of vegetables. That action is in very few cases to be perceived in the direct and actual performance, but only in the result; thus, even in the most rapidly growing plant, we do not see the increase of growth, while we actually observe it; and though a man were capable of standing to watch a plant, from its first appearance above the ground to its final decay, even though it were an oak of an hundred years, or a deodara cedar of a thousand, he would not be able to perceive the least change of it at any two consecutive moments of his observation; and, indeed, in common cases, they who are in the daily habit of observing the same vegetation, are sensible of very little change in it from day to day, unless in the course of some very great change in the weather. *But though vegetable* action is thus invisible to us

in the performance, we must still judge of it as we judge of other actions, and suppose, that in every case there is a resistance to be overcome, without which resistance no action could possibly take place.

The membrane of the cell or vessel, in the individual instance, affords its own resistance, just as the vessels of the animal structure afford those resistances which enable the internal actions of the animal to be carried on; but gravitation, as inherent in the matter of the plant, and inseparable from that matter, is the grand resistance against which the whole structure of the plant works, when it elevates itself in the air, or expands laterally. And we have in this the same yielding to the power of gravitation in the cellular substance of the plant, which we have already noticed in respect of its yielding to the action of the sun; for if a lateral branch of a tree has been freely exposed to the air, and met with no accident, we invariably find a greater accumulation of matter upon the under side, or side toward the ground, than there is upon the side toward the sky; and it is impossible to account for this in any other way than by the effect of gravitation upon the cellular structure, when that was young and soft.

The action of light upon vegetables is also very powerful, though it is different from that either of heat or gravitation. It is true, that in plants which grow in free nature, exposed to the elements, we cannot very well draw the line of distinction between the action of light and the action of heat, inasmuch as that both come in the same rays of the sun, or in the reflection of those rays from the atmosphere, or from the earth; but there are

certain experiments which enable us to form a judgment of this matter, which is subject to no source of inaccuracy, and which is at the same time highly instructive. If a plant is excluded from the action of light, it ceases to produce the usual quantity of carbon or charcoal, in those parts of it which usually contain the most of that substance; and, generally speaking, it becomes pale in the colour, weak in the structure, and juicy and comparatively destitute of fibres. There are familiar examples of this in cabbages which close naturally, in lettuce plants which are tied up, and celery which is earthed up. These operations are called blanching; and all plants which grow in the dark, or with a deficiency of light, are thus blanched, and run along with feeble stems, as if in search of the light, or attracted by it, which species of diseased growth is called *etiolation;* and we believe that no plant, completely deprived of the light, will form wood, or even a distinct vessel, but remains tender and cellular, and subject to the same speedy decay, as a young bud, or a twig newly shot out, when broken off from the parent plant.

There is no doubt that electricity, and the other general modifications of natural action, have an influence upon plants, proportionally greater than they have upon animals; but their effects have not been investigated to a very great extent, and the investigation of them is so exceedingly difficult, as to be beyond the province of popular observers.

CHAPTER III.

DIFFERENCES AND DISTINCTIONS OF VEGETABLES.

THE vast number of vegetables specifically distinct from each other, and the endless varieties into which many of those species are broken by variations of natural circumstances, or by human ingenuity in the art of cultivation, which, whether the object is beauty or usefulness—and beauty, in the cultivation of vegetables, is far from being without use, inasmuch as the contemplation of fine forms and beautiful colours tends greatly to soften the human heart—renders it necessary that the most skilful arrangement should be made, in order that we may have even a very moderate and imperfect knowledge of this delightful kingdom of nature. The plants already discovered, when classed according to the systems of the most intelligent and industrious men who have devoted their attention to this department of knowledge, amount to little short of four thousand genera; and those genera include between thirty and forty thousand species; while the varieties, which are increasing every year, are absolutely without number. In so extensive a field of study, there is something that would appal even the most undaunted mind, were it not that this field is as inviting as it is extensive; and it is impossible that the student of plants can be sufficiently grateful to those illustrious men who have spent their days and nights in showing that there is order, and very delightful order, in those which, to the eye of *the inexperienced*, seem altogether confusion.

It is impossible to found a classification of plants upon any of those distinctions between them to the eye of an inexperienced observer, and which have in consequence obtained names in the popular language of every people who have been sufficiently advanced in civilization to notice the varieties of plants; and this is one of the subjects to which attention is very early drawn. The most remarkable distinctions which strike the unlearned eye, are those of the sizes of plants and their habits of growth; and, according to this view of the matter, there are five leading divisions. First, trees which attain to a considerable elevation;—and, generally speaking, last for a number of years;—secondly, shrubs, which are similar in their habits, and also in their duration to the former, but which are a more lowly growth, and generally speaking present a number of slender stems, instead of rising with one majestic bole, as is the case in the more typical kinds of trees;—thirdly, herbaceous plants, or those which never form any wood, properly so called, and of which the stems are, generally speaking, annual;—fourthly, earth plants, or surface plants, comprising those which do not elevate any distinct stem above the surface on which they grow; and some of which only display to the light those parts which contain their fructification, as is the case with many of the mushrooms or fungi; and others, such as the truffle, which is also a fungus, do not come above the surface of the ground at all, and a few grow darkly in caves, and other places which the sun never reaches;—and fifthly, aquatic plants, or more strictly speaking, marine plants, for the *plants of the fresh* waters are sometimes not *very different from* those which grow in humid

[illegible] and, and like them, most of them. [illegible] in the mud at the bottom [illegible] fresh earth plants as well [illegible]

[illegible] examine the nature of the [illegible] find that though [illegible] enough for simple [illegible] as leading to [illegible] as from one [illegible] erring manner. [illegible] course [illegible] some other [illegible] have been [illegible] indications. [illegible] the [illegible] general [illegible] important [illegible] its [illegible] without any [illegible]

as virulent compared with our nettle, as they are superior to them in size. Some of these tree nettles are so formidable that it would be worth while to mention them as showing that the prickles of vegetables may be armed with as deadly virus as the fangs of serpents. Nor is it unworthy of remark, that the very same excessive natural action which gives the most exquisite flavour to wholesome vegetables, is also that which concentrates the most deadly virus in those plants of a different character. The *urtica crenulata*, and *urtica stimulans*, both of which are found in the exuberant islands on the south-east of Asia, and another one found in Timor, one of those islands nearest to Australia, and called *Daoun Setan*, or the "devil's leaf," by the natives of that island, is still more formidable. M. Leschenault mentions that he was stung by *urtica crenulata*, the leaves of which were slightly touched by the first three fingers of the left hand, while gathering a specimen for his herbarium. He was stung at seven in the morning, and he says he felt only a slight pricking, which he totally disregarded; but the pain gradually increased, and in the course of an hour it had become intolerable; and, although there was no remarkable external appearance, either of swelling, blister, or inflammation, yet the parts felt as if they were being rubbed with a hot iron. The pain soon extended all over the arm up to the armpit; and about noon he was alarmed by an agonizing contraction of the muscles of the jaws, which made him dread an attack of locked jaw. He was also affected with frequent sneezing, with copious running at the nose, and so violent were his sufferings, that he went to

bed; but even then he experienced no immediate relief, for the agony continued the whole of the evening and the night. About seven o'clock, however, the symptoms of locked jaw disappeared; and as the morning advanced the pain had so far abated that he fell asleep; but still he was not entirely free from pain for nine days; and whenever during that time he put his hand in water, the pain returned with nearly the same violence as at the first. It is understood that the sting of the Timor plant is still more severe than this, and far more dangerous. The effects of it are said to last for a whole year, and it not unfrequently produces death. Some time ago, one of the men in the Botanical Gardens at Kew was very seriously affected by inadvertently touching a plant of this kind with his naked fingers. In the course of a short time his arm and head were very much swollen; and a most painful eruption broke out on several parts of his body, which every application aggravated, and he was obliged to endure it till it naturally wore off. It is highly probable that the fictitious story of the dreadful effects of the upas has been originally framed by confounding together the properties of these trees which yield a poisonous extract without being dangerous to the touch, with the tree nettles now mentioned, which are so dangerous to the touch, and yet yield no poisonous extract; and there is no doubt that if the properties of the Bohun upas (*Ipo toxicaria*), and the nettle tree of Timor were united, they would realize at least part of what the fables told of the upas, though the one tree is just as harmless to birds flying over it as the other; and therefore there would still remain enough to

mislead the ignorant in those stories which, once told, are still repeated in but too many of the popular books.

The contrast between the herbaceous ferns, and the arborescent or tree ones, is still greater than that of the nettles; for though the tree ferns are many of them of stately growth and perennial duration, they preserve almost exactly the same mode of growing as our ferns; none of which have a stem, properly so called, separate in structure from that which appears the leaf, but merely a *frond* or green expansion, springing from the root, and variously modified according to the species, though in all our native species dying down every year. Nor is it less worthy of remark, that, in many accumulations of vegetable remains which are found imbedded in the earth in Britain, and even in countries farther to the north, there are among these the vestiges of many other plants, unknown to the native botany of the same regions as now living, the vestiges of tree ferns, rivalling in size those which are still met with in countries within or near the tropics, and more abundantly in the southern hemisphere than even in the tropical parts of the northern.

Those circumstances, and especially that of taking in the progressive botany of the earth, as found in the buried records to which we have alluded, render the proper classification of plants a matter of great difficulty; and one which can hardly yet be said to be reduced to a permanent character, capable of being expressed in an abridged form for popular purposes.

In *the preceding paragraphs* we have mentioned *the words "botany"* and "botanist;" and, for the

sake of such as may not have turned their attention to the study of plants, it may not be amiss to mention the meanings of those terms. The word botany literally signifies a grass, or that which constitutes the food of a browsing animal, which lows or bleats, and is guided by the herdsman or the shepherd. This name has been long used as expressive of all plants, and also of the science or knowledge of plants, or the cultivation of them with a view more to the understanding of their nature, than to the turning of them to commercial profit; and a botanist is of course one who understands the science, or who practises the art. This being explained, we may proceed to the principal grounds of distinction.

In this there are nine gradations, each of which is a subdivision of the one preceding it; and thus, as we proceed downwards, the number requiring separate explanation and description gets greater and greater. It is of little consequence by what names the different gradations of this scale of plants are called; and therefore the best is the shortest, and that which is most generally used. The names usually given are grand divisions, which is the stage or step immediately below the whole vegetable kingdom, classes, subdivisions of classes, sub-classes, orders, families, genera, and species. These are only eight in number, but they are supposed to descend as far as nature descends in the ordinary habits of the plants; but climate, situation, culture, and various other circumstances, cause many more minute divisions, which get the name of varieties; though in the case of every variety it is understood that there is a constant tendency in the plant to return to the original or

common type of its species, if placed in that soil and situation in which it naturally thrives well under that type, and if left there to breed for a considerable length of time.

Grand Division. These are formed upon the general structure of plants substantively, and also upon the general mode of growth ; but sometimes these do not harmonise, and the introduction of too many principles is apt to occasion confusion. The most simple view of the matter—namely, that which depends wholly upon the structure of the substance of the plant, and not upon the mode of its production and growth—is that which takes the two leading characters of vegetable substance, *cellular* and *vascular*. The cellular plants are of course, wholly composed of cells in their contents ; and vascular plants are those in which the cellular matter is more or less intermixed with tubes, or fibres of various forms ; the first of these being the organs which are properly termed vessels, though it must not be understood that those vessels bear the slightest analogy in their functions, to the absorbent or circulating vessels of animals, or to the air tubes, by means of which some of the invertebrated animals breathe.

There is another distinction, very closely, though by no means invariably, connected with this one ; and that is the mode of reproduction in the plants. If the plant has no visible organ answering to what we generally consider a flower—though in that respect our judgment is very vague, for, as we have said, the part of a mushroom, and indeed of most of the fungi which appears above ground, is really a *flower* during one part of its existence,

and a fruit during the remainder, the seeds of which are often exceedingly numerous, and so minute that the eye cannot discern them singly—such plants are said to be *cryptogamous*—that is, the act of production, by which the principle of vegetation is imparted to the germ, is secret or hidden; but though it is so to our observation in many cases, though not in nearly so many as was once supposed, there is no more doubt of its existence in those cases in which it is impossible for us to trace it, than there is in the others in which it is most conspicuous. Of course all the notions about the production of new races, even of the humblest and most minute of those cryptogamous plants, in any other way than by a regular descent from a parent plant, are now exploded by every person possessing even the most limited knowledge of the physiology of vegetables; and though there is hardly a species of plant, or an animal substance, which does not in a certain stage of its decay produce its fungus, and a fungus different from that produced by that of almost every other plant or substance, yet no one who reflects on the matter in these days ever supposes, or has the least tendency to suppose, that the germ of the fungus is originally produced by the substance on which it makes its appearance; for the fact is, that the exceedingly minute seeds or germs of those fungi are, like the very minute eggs of some of the invertebrated animals, proof against the ordinary contingencies of the atmosphere, and, as it should seem, also against time itself; and therefore they are always ready to avail themselves of every situation and substance favourable for

their development; or rather, there is no availing in the matter, for they passively obey those circumstances which call them into action.

Plants which have visible powers as organs of reproduction, are called *phenogamous*, which is merely a sort of Greek expression for the fact of the flowers being visible; plants of this description are the most majestic in their growth, the most beautiful, and the pulpy envelope of the seeds of many of them, which is known by the common name of fruit, is often more pleasing to the taste, than any other production of nature, whether animal or vegetable. But though plants of this grand division, or rather having this mode of production, are always more or less vasculated in their structure, and can all be produced from seeds which are elaborated by the action of flowers, yet this is not the only mode in which very many plants of this kind may be obtained; for some produce new plants by their roots, and there are others from which a cutting can be taken, and this cutting, set in a proper soil, will in time produce a plant; and so strong is this latter power in some of them, that the cutting may be placed with either end in the ground, and will grow equally well, whether it is the one way or the other. It thus appears that, in these plants at least, the production of a root or a branch depends upon the circumstance of the part of the plant on which it is produced being situated in the air or in the earth. There are also several plants—the celebrated banian tree of India, for instance—which send down fibres from the lateral branches; which fibres take root in *the ground*; and by this means the *tree, in the course of* time, may acquire many

hundreds, or even many thousands of stems; and thus stand rooted over a great extent of ground as one solid and connected forest, impregnable to the most violent storms of the tropical atmosphere. The modes of this supplemental production, in addition to that by regular seeds, are both numerous and varied, far too much so for being noticed in this compendium; but it is necessary to allude to them as a caution against supposing that, although the plants have visible flowers and seeds, they cannot be produced in any other manner.

There is another distinction of phenogamous, or, as we shall now call them for the sake of brevity, flowering plants, which is worthy of notice; and that is the manner in which they increase in substance by the operation of the principle of growth. Of this there are two distinct modes, which are never interchangeable with each other. The one is called *endogenous*, and the other *exogenous*.

Endogenous plants are those of which the growth continues at and from the centre; and such plants, even when they are very tall and stately—as is the case with many of the palm family, which are so beautifully characteristic of the scenery of warm countries, and the products of some of which are so highly useful to the people of the countries in which they grow—do not increase in diameter or thickness as they increase in height; but the stem continues to rise with the same diameter which it had at the first, although it may ultimately attain the height of a hundred feet or upwards. In some plants of this description, however, the *collar* (*afterwards to be noticed*) which is in many plants the *grand seat of* vegetable life, and the only place

w plants can be obtained otherwise than is raised a little above the surface of the and bulges out into a larger diameter; ch new roots are sent down surrounding ıal one; and where this is the habit, it is accompanied by an increase in the dia- the stem; but the particular way in e enlargement of the trunk results from litional roots has never been properly exa- understood; only it is certain that they ;ive rise to any corresponding branching per part of the tree.

l endogenous plants, whether of short or of long—and some of them continue to grow for many ages—there is, in the typi- es at least, only one bud; and this bud ;he top of the axis, or central line of the the tree, containing in a plant of vigorous ar more energy, and possessing far more material for the increase of its develop- ın is found in any one part of a many- ree of the same volume. This single bud r changes to a flower, but always mounts producing leaves as it ascends; the old ropping off or withering away after a leaving scars or cicatrice; more or less on the stem. The flowers are produced illæ, or angles formed by the leaves, and of the trees they are of great beauty, and ımber. The fruit also is often very abun- highly nutritious; but it varies so much m and characters, that it does not range species under any of the denominations ith *which* we are familiar in this country. *te palm*, for instance, it is a fleshy pulp

covering a hard kernel; and in the cocoa-nut tr
it is a pulp enclosed in a shell of substance as co
pact and hard as almost any kind of timber, whi
again is covered by fibrous matter, and a me
branous rind which bursts asunder when the fr
is ripe. This endogenous growth, though a stri
ing character of all the plants to which it belon
is thus not of so general a nature as to take all t
other parts of the plant along with it, and the
fore it cannot be taken singly as a specific grou
of classification. Still, however, it is one of t
elements which are essential for arriving at a co
rect knowledge of the nature of the plants.

Plants which have the other mode of growth,
are exogenous, do not grow at the centre; a
though more or less of the central parts contin
capable of action according to the species, and a
according to that obedience of plants to circu
stances which was mentioned in the precedi
chapter; yet the central part grows no further
that is, makes no more increase of substance—af
the first seasonal pause, during which the pla
hybernates or remains inactive until a different st
of the weather calls it into fresh activity. Pla
of this kind increase by an annual layer or pr
duction of matter which encases all those parts
the plant that were sound and in health at its co
mencement; and thus, a tree of a thousand yea
which has the habit of growing by terminal bu
or buds at the ends of its branches only, migl
if it were possible mechanically to perform t
operation, be separated into a thousand trees, ea
inclosing its predecessor, and containing few
branches than its successor; but all so beautiful
fitted into each other, as that the whole sho

ɔ empty space. This cannot of course be
ıractice in the case of any one tree; but
;ree, of which the annual productions or
re very conspicuous, as they are in a com-
s divided longitudinally, we can distinctly
trees of the different years, as far as the
ɛtends. Not only this, but the different
tenacities of different years' productions,
rt of record of the various seasons during
tree has stood; for if the season has been
ı usually favourable to vegetable action,
.ction of the year is larger than common,
t has been unfavourable, it is smaller than
This is not all which we can learn from
of a tree when divided in this manner, or
ı divided across so as to show the different
ends of the cylinders of wood. If the
s not excessively hot, and if the return of
: is gradual, so that the wood ripens, as it is
y called, then the early part of the year's
n is tolerably compact; and the latter part
ɔeaking more especially of a pine), is very
ınd hard. On the other hand, if the heat
ımmer is great, and the chill of winter
suddenly and severely, the produce of the
espect of wood may be, and generally is,
eater than in the former case; but the
; timber is very inferior indeed. That
produced in the early part of the season
allude to the pine), is soft and fungous;
ıiss altogether the compact portion which
ıe intervening autumn, or that the wood
properly ripened.
ɛr to show what practical advantages may
l from the careful study of even the most

apparently trifling particulars in a single department of nature, we may mention how the climate of the north of Europe, of Sweden and Norway, for instance, and the climate of North America, more especially that of the province of New Brunswick on the south side of the great river St. Lawrence, tell upon the timber which they produce, in very nearly, if not exactly, the same original species of tree. The summer in the north of Europe, though considerably warmer in proportion to the winter, than it is with us, is not nearly so warm as it is in the part of America alluded to, or indeed in Canada generally; but though the situation of New Brunswick is full ten degrees, or seven hundred miles, nearer the equator than the average latitude of Norway, the winter there is vastly more severe than the Norwegian winter. Not only so, but in that part of America the changes of the seasons come with great violence, so that there is scarcely any thing which can be called either spring or autumn. When the frost relents, the rains of the early season descend in torrent floods; and, at the close of the year, the return of winter is equally sudden and violent, so that between a day of almost the temperature of the tropical regions, and one which outdoes Lapland in the severity of its cold, there intervenes but a single night; and on one day the pitch on the side of a ship will be melting, while the next day a pail of water cast up in the air will come down rattling in the state of ice. The consequence of this is, that there is no ripening —no autumnal maturing of the timber of trees, in the Canadian climate; and the consequence is, that the pine timber grown in that country, on what *land soever it* may grow, is altogether differen

ıd vastly inferior to, the pine timber which
ı any part of the eastern continent. There
rences of species; but in the best of them
a decided inferiority to the very worst tim-
uropean growth, so that by the time that the
dry it is nearly rotten; and though, from its
l the ease with which it can be worked, and
n the most unwise favour which it has found
yes of the British Legislature (unhappily,
riably gifted with, or guided by, science),
een largely introduced, and has given to
buildings, in many parts of the country,
ition of a mushroom and the frailty of a
l.

s which grow in this exogenous manner, or
al accumulation of wood on the outside of
ch was previously produced, differ from the
ous ones in a very remarkable manner. The
ıe endogenous plant is confined to the axis
al line of the stem; and it never quits that
that, as the plant ascends, the new produc-
superposed upon the top of that formerly
d, and all the lower part is of an elder
than the part above it, the external portion
ways the oldest production, and the least
l with the principle of vegetable life; which
ıch plants is, as has been said, confined to
, so as, in most of the species, to be life
ng in the direction of a single line.

e exogenous plant, again, the vital principle
n the surface of a cylinder, or cone, accord-
ıe habit of the tree; and this living surface
as the tree increases, both in circumference
length, whereas in the endogenous plant it
n the length only. There are many modi-

fications of this principle, of which it is not easy to give a distinct account. In some families of exogenous plants—as for example, in the whole of the pine family—there is a mode of growth approximating in some respects to that of endogenous plants; but in them the bud continues, though with lateral productions in every year, or season of growth; but still there is only one bud, whose function is to lengthen the stem or the branch; and if this bud is destroyed, it cannot be reproduced, and consequently the tree is mutilated. In trees which have this habit, if the whole of the buds were to be destroyed in any one season, the tree would grow no more; but would merely linger until such leaves as it bore were cast off; and then it would gradually decay. Trees which have this habit are, generally speaking, evergreens, that is, they retain their leaves during the winter; but in them we must not confound an ever-green tree with an ever-growing one; for, according to the climate in which it is placed, the ever-green has its pauses in the same manner, and for nearly the same time, as the deciduous tree, which throws off its foliage in the season of repose; and though the leaves may remain for a whole year, or even for a longer period, there is only one growth in them, and though they retain their greenness, their vegetative function ceases when the period of their growth is over; and whether they drop off after a year or after a longer period, they become inactive as soon as the new succession advances to occupy their place. We have very familiar instances of this in the common laurel and the common holly, which are plants that come under every body's notice. They retain their leaves in a green state, and apparently undecayed durin

the winter; but their vegetable function ceases before the winter, almost as completely as the function of those leaves which fall in the autumn; and when the young shoots and leaves begin to make their appearance in the spring, they have very different properties from those leaves which have stood the winter. For instance, if the temperature of the young leaves is tried by a thermometer while the sun rests upon them, they exhibit that degree of cold which is very variably characteristic of green vegetation; but, if the old leaves are put to the same test, it will be found that they, in proportion as they advance toward the time at which they are to be thrown off, exhibit nearly the same susceptibility to heat as if they were not living matter.

Every endogenous plant may be considered as proceeding from a centre, and along an axis, while plants which are exogenous proceed from a circumference. This circumference is best understood by reference to some tree of perennial growth; because it is not absolutely at the external part that the growth or increase of substance takes place. There is, as it were, an external and an internal cylinder in any portion of the trunk of a tree of perennial growth. The external cylinder is the bark of the tree, which though it differs greatly in the proportions of its volume in trees of different kinds, never acquires the same compactness, or the same fibrous texture, as the internal part of the tree. This internal part, or inner cylinder, in a tree which has grown some time, is the wood; and though, as has been hinted already, a portion of this wood retains its freshness and sap, and performs some kind of vegetable action, for more than a year, yet the seat of life

in the tree, or in any part of the tree, is not to be considered as extending over a definite thickness of this inner or woody cylinder. As little does it extend over a definite thickness of the bark. It is at the boundary between the two that the tree lives, and how small soever the thickness of substance in which the life is actually seated may be, no one can tell; but the probability is, that it is a mere surface, or rather the meeting and co-operation of the two surfaces of the bark and the wood. When indeed we attempt to trace the seat of any kind of life, we are always reduced to the same difficulty, and landed in circumstances much more nearly similar than we would be apt to suppose; for when we take animal life in its rudimental state, we find some mysterious action in a membrane, which is actually parted in two, and one part of it is maternal, while the other belongs to the new life. So also whenever we attempt to trace the life of an exogenous vegetable to its source, we are sent from the epidermis of the bark inward to the wood, or from the wood outwards to the bark; but we are unable to fix upon the precise locality, and to say, "The life of the plant is seated in this."

We can, however, observe the development with the same ease as though we could define precisely the seat of life as a distinct part of the structure; and this is all that is necessary for our purpose. The young growth of such a plant is the longitudinal extension of a cylinder; and the new layer which is applied to the surface of growths of the former year, is the increase of a cylinder in diameter. We cannot suppose this to proceed from a mere line; and therefore we always find more or less of a *soft medullary*, or rather cellular substance in the

central part of a young stem, which substance is technically called the *pith* of the tree. The name is not a very happy one, because in every other sense and every other use of the same word which retained in the language, is nearly synonymous with strength; and this pith of the tree, instead of adding anything to the strength of it, is the weakest substance in it. It appears to answer chiefly as a support along which the cylinder expands; and when it has performed this function, it ceases to be of use in the economy of the plant; and though in many young subjects it is in large quantity, yet in old ones it is often entirely obliterated by the pressure of the surrounding parts upon it.

It will be perceived that there is some resemblance between those two modes of growth in plants, and the systems of the animal kingdom; and that the endogenous plant bears a very great resemblance to a radiated animal; although, generally speaking, there is not the same distribution of the reproductive power through a plant of this kind as there is through the body of the radiata. Still, however, there is this resemblance between them, that the perennial trees of endogenous growth leave a portion under them, at least on the external parts, in which the functions of life have ceased, in the same manner as those radiata which have fixed situations, and elaborate stems often bearing a considerable resemblance to plants, leave the stem behind them and grow in shoots; and some of them at least have this farther analogy to the plant, that they maintain a connexion by means of an internal tube reaching to the beginning of the stem.

There is yet another resemblance which is worthy of notice; and that is, what subsists between some

radiata, some endogenous plants, and the multilocular shells, or those which contain a number of separate cavities, sometimes having a pipe of communication, and sometimes not; but it being understood that in all cases the active part of the animal occupies only the last, or most recently formed of those cells or chambers. The most extraordinary part of the matter is, that they are found fossil in our latitudes where endogenous plants, of more than a year's duration, are hardly known in one living specimen; and the shells in question are little known anywhere, and the economy of their inhabitants is not known at all; so that it is only by inference that we suppose they are molluscous animals. But when we turn our attention to the remains of former times, we find that almost the entire vegetation of the very countries in question has once consisted of endogenous plants; and that along with them those chambered shells have existed in countless myriads.

It is true that the particulars now mentioned do not furnish us with the exact history of our portion of the earth in those early days, neither do they so much as fix the date to let us know how many years and ages have rolled on since coal mines were groves of palms, of ferns, and tree nettles, and limestone quarries living inhabitants of the sea; but when we come to look at those portions of the earth which still abound with large endogena, and find that there are recent chambered shells found there also, we are entitled to conclude that at the period or periods when such were the production and inhabitants of our latitudes, their natural circumstances must have in some respect resembled the countries in which those productions

are still to be met with. They are met with in tropical countries, where there is a much greater degree of action of every natural cause than at any other part of the earth; and though the extremes are moisture and drought, and not heat and cold, yet as we find the endogenous tree with its working structure in the axis, or shielded by the whole mass of the stem, while the exogenous one is near the outside, it is impossible to avoid coming to the conclusion, that there must have been much greater alternations of season in our latitudes during those early days than there are now; but that, however great the change may have been, or however often change has succeeded change in the transition from that early state of the country to its state now, the very same general laws must have been in operation then which are in operation now; and thus we have the clearest proof of the unity of creation in the longest period through which we can trace it, as in the momentary view which it presents to the eye.

Classes of plants, or of any other natural productions, are merely artificial arrangements; but still it is desirable that they should be founded as much as possible on natural characters which are clear and distinct. The lobes of the seed, which in the case of many plants answer the purpose of leaves, until the plant is so much established as to be able to put out leaves for itself, and which are called the seed leaves, are used for this purpose; and it is remarkable how many of the general characters of the plant follow this arrangement, so as to render those lobes of the seed a very useful *index*.

Those seed lobes furnish three classes, Acoty-

ledoneæ, or those which have no lobes in theseed; *Monocotyledoneæ*, which have only one lobe; and *Dicotyledoneæ*, which have two lobes; and those three classes rise higher and higher in the general development, according to the number of the cotyledons as above stated.

Those without cotyledons are the flowerless plants; and they are remarkable for the similarity of the different parts of their structure, the obscurity of their modes of reproduction, and, generally speaking, for the small share which they all hold in ornamenting the fields. Some of them, indeed, are little else than a jelly-looking mass; and as this mass is often of a deep red colour, and appears suddenly in certain states of the weather, it was often in the days of superstition represented as blood which had been showered down from heaven, and which portended some direful calamity. In itself, however, this is the most simple of all organic productions, and one of which the duration is very fleeting. Plants of this class are much more abundant in the cold regions of the world in proportion to the whole vegetation of those regions, than they are in the warm regions; we meet with them the last on the mountain top; and they are the only class of plants which grow and carry on all their functions, though submerged in water. They are the last which we meet with toward the polar snows; and when the character of a district of country falls off, it is usually indicated by an increase of plants of this description, more especially those kinds which encrust the rocks, in those dreary and dripping hills where there is hardly a flower to be seen at any season of the year. Others, such as the whole tribe of the fungi, dwell in richer places;

hey appear to have a very important office to rm in the seasonal phenomena of many coun- ; in all countries, indeed, except in such as are ·kable for habitual dryness. Among those ı perform a seasonal labour, the most nume- and certainly the most peculiar in their habits, he fungi. These present themselves every ; ; the seeds or germs of all of them are ex- ıgly minute ; and many of the plants them- ; are so small, that they are invisible, and yet are so abundant and so active, that they do lerable damage to the cultivator. Some of are known as rusts or blights upon corn and ıs other plants ; and though they greatly dimi- the useful product of the plant, and render remains unpalatable and unwholesome, it is se effects only that they are seen ; and there- he ravages which they commit can hardly be nted by any positive remedy. From the fact ertain state of disease or decay in an organic ınce of any kind being always accompanied ıe production of one kind or other of those us plants, we are led to conclude that protec- rom their mischievous effects is to be sought general management, and not by any specific dual treatment; and we are guided in this al management by the circumstances under those fungi which are sufficiently large for bservation present themselves. Now this is s when the moist season sets in,—the time of ıtumnal rains, when the leaves begin to decay ; herefore a damp atmosphere is the general tion which subjects a country the most to minute but countless destroyers. If, there- *he farmer wishes* to obtain plentiful crops of

sound and healthful corn, he must take care that the said crops enjoy a dry and healthful atmosphere during the period of their growth. In order to secure this he must beware of the marsh, and see that his hedges are trimmed and his ditches cleared; because, if he allows vegetation to grow in stagnant water, or to fester and rot there, he disseminates the means of poison over his land, and thereby defeats his own labour. Nor is it unworthy of notice that this state of the fields, which is essential to the obtaining of abundant and wholesome crops, is also that which is most favourable for the health of man and of all useful domestic animals. It thus conduces equally to pleasure and to profit, while the field of the sluggard is both unprofitable to himself and injurious to his neighbour.

The tenacity of life in many species of those plants is as wonderful as the extent to which the germs of them are distributed. Many of the mosses may be kept in a perfectly dry state for a number of years, and yet if put in water they very speedily regain their living colour, and begin to vegetate. Nor does it appear that there is any difference as to which part of some of those plants is preserved; for any of them will grow, even in some of the species which have also local receptacles for at least some of their germs.

The second class of plants, or those which have one cotyledon or lobe in the seed, are far more important, as comprising many of those plants which are most serviceable as articles of food, and not a few which add greatly to the beauty of the earth. The most interesting of the whole class *are the grasses*, which are the characteristic vege-

tation of temperate climates, and of rich surfaces by the banks of flowing streams. In a state of nature they form the chief food of all the grazing animals; and in cultivation, the bread corn of all nations is a grass of some description or other, the farinaceous part of which has been increased by human art, though probably the improvement of the quality was not the positive intention of the first cultivator. It could not indeed be, because it is a matter of experience, and must have occurred before any explanation of it could be given.

It is not a little remarkable that our common wheat and our other species of grain have no types in wild nature; there are plants resembling them in many particulars, but there are none which afford the same quantity or quality of nutritious matter; so that it is impossible for us to say of what country those plants are natives. Not only this; for we are as ignorant of the fate of those plants as we are of their origin; when wars or other calamities turn a once cultivated country into a wilderness, all the cultivated plants disappear; and not only so, but after a time the fields become unfit for their production, until the hand of cultivation has been for some time exercised upon them.

We can trace the progress of degeneration in slovenly fields in our own country. Change is the grand law of nature, for action is change; and it is the change produced on the cultivated plant, in the soil in which it is placed, and the treatment to which it is subjected, that the advantage consists. If the plant is allowed to sow itself naturally, and if it is an annual, as the grain plants are, then there is an annual distribution or sowing of the plant *naturally*. *This*, of course, takes place imme-

diately when the seeds are ripe, which, in countries like ours, is about the time of the autumnal rains. The self-sown seeds of annual grasses could hardly produce an entire crop in this way, because they would be exposed to the action of the air and the weather; and in the case of even an admixture of perennial grasses to protect the seeds of the annuals, the annual seed would labour under the disadvantage of having the nourishment shared with the perennial one. But when the seed is gathered when ripe, carefully dried, and stored up to be sown at a proper season, it is preserved from all the contingencies of the weather. But it is a law in all the working of nature, that if we can encourage any particular part of an animal or a vegetable, by means of artificial treatment, the whole organisation will work along with us in the improvement of that part, in quantity or in quality, according to the skill which is displayed by the cultivator. This is a very beautiful adaptation; and where the trial has been made, it has been found to be as extensive as it is beautiful. Those who have studied with proper attention the methods of breeding domestic animals can proceed upon almost any quality they please, size—general form, shape of particular parts, texture, and length of covering, quality, and even particular flavour of flesh. But vegetables are still more under the controul of external circumstances than animals are; and therefore they offer a far wider range to the cultivator; and when we consider how much human life depends upon those plants, it is impossible that we can too warmly admire and encourage those who devote their time and talents to the principles *of this study*.

It would be impossible for us, in a mere sketch, to enumerate even half the names of the orders of plants which fall under this second class. The palms, which are the characteristic vegetables of the warm latitudes, are included in it; and they are perhaps the most majestic of all vegetables, and next to the grasses, for which the extreme heats of tropical countries are not so well adapted, they are among the most useful. All bulbous and tuberous rooted plants are also comprised in the same class; and of tuberous roots we may instance the potato as contributing perhaps as largely as any plant or substance whatever to the sustenance of man, though its introduction is but of yesterday compared with most other cultivated plants.

In the roots of plants, especially those which have their stems and productions annual, and thus come under the old but not very correct division of herbaceous plants, there are some remarkable instances of adaptation to the physical or climatal circumstances of the several regions of the world in which they are produced. The grand distinction of regions in this respect may be taken as three,—tropical, temperate, and polar; but it is to be understood that no where in the surface of the earth can a line be drawn which marks the definite boundary at which one of these distinctive characters ends and another begins. The earth is spherical, and though a little flattened at the poles, and elevated at the equator, or circumference midway between both poles and tropics, it is so nearly a perfect sphere, that if a meridional circle or circumference of it passing through both poles were drawn, it would require an eye well expe-

rienced in geometrical forms to find out that this delineation were not an exact circle. The action of the sun diminishes in a certain proportion as the surface becomes less directly exposed to it. When the action is perpendicular, to use the geometrical expression—it is a maximum, or the greatest possible. It is so for two reasons, or, strictly speaking, for three; the atmosphere which surrounds the earth, though invisible to the human eye, and imperceptible by any of the senses, except when naturally put in motion in what we call winds, or felt by our own motion, as is readily done by moving the open hand briskly backwards and forwards, or by playing a fan even in the most tranquil apartment;—the atmosphere, though thus partially within the cognisance of the human senses, and though the finest instrument which human ingenuity can construct cannot distinguish one single particle of it as a separate piece of matter having form, is yet capable of receiving or interrupting light and heat, and every other modification of the wonderful emanation of the sun. In consequence of this, and of the weight of the atmosphere causing it to assume a figure something similar to that of the earth, the perpendicular rays of the sun have a less distance, or height of atmosphere, to pass through than the oblique and slanting rays. It is the nature of every substance upon which a warming and illuminating emanation falls, to reflect off a greater o less portion of that emanation, according to th nature of the substance, and especially according the colour and quality of its surface. So perfect minute and searching is this heating and illun nating emanation, that it finds out the invisible p

ticle, and tells upon every atom of the atmosphere in the very same manner, proportionally to its size, as it does upon the earth itself, or upon any other body of large volume; as, for example, upon the moon, which, being nearer us than any other of the heavenly bodies, and giving light only by reflecting the light of the sun, is the best subject to which we can refer for illustration of the reflection of the solar emanation. That emanation, considered as light, or compounded of every tint and tone of colour which we can imagine, proceeds, when coming directly from the sun, in the very same line of direction as the same emanation considered as heat: but when reflection takes place at the surface of any portion of matter, however large or however small, the heating portion of the energy is more stubborn than the illuminating one, and the portion of it which is reflected does not go in the same direction. Hence the moonlight is cold, and hence also the light of the morning dawn and of the evening twilight are cold, very often colder, especially in the dawn, than the darkness of the night; for light, even though reflected without heat, produces an excitement of the feelings which is not produced by darkness; and this is the reason why we are more sensible to cold in the grey of the dawn or twilight, though the absolute cold, or more strictly speaking the absence of heat, may not be greater in the one case than in the other. The atmosphere which sends us twilight is to be considered as composed of a countless multitude of little moons, each of them far too minute for the eye or the microscope, which continue to shine as long as the light of the sun falls upon them; and

enever they reflect the sun's light down to the face of the earth, the sun's heat always goes off another direction.

This short view of the action of light and heat pon the atmosphere, is not only necessary for enbling us to form a due understanding of the manner in which, according to the direction wherein it falls, the emanation of the sun acts upon plants, but it will save us some explanation in a future chapter.

We are then to understand, that where the sun's rays fall directly, they come through the shortest possible distance of atmosphere, are least broken or reflected by that atmosphere, and consequently tell most forcibly upon the surface of the earth, and every thing which that surface presents. But farther, the atmosphere itself, which is a means of breaking and dispersing, and therefore of weakening, the oblique or slanting emanation of the sun, in which it increases in proportion to the obliquity, is a means of increasing the direct emanation, inasmuch as the portion which is reflected upwards from the earth's surface, and which as it comes down in the perpendicular is reflected in the same, still returns in the same to the surface of the earth, and by thi means considerably increases the effect of the sun' direct action.

In the regions of the poles again, if we take t average of the year, the light of the sun pas parallel over the surface without acting upon and it passes through the maximum extent atmosphere, so that in proportion as the sun is the solar light is dispersed by the atmosph though in such cases, the extent and the brigh *of the twilight* must be greater than when the

light falls directly, inasmuch as there is a greater volume of atmosphere to act as a multitude of indescribably small moons.

The consequence of these is, that at the equator, and for a considerable distance on each side of it, comprising all the middle or tropical zone of our earth, there is an excess of solar action, so great that, but for the seasonal changes which arise from a very simple but very beautiful part of the earth's economy as a planet, would not only drain every known vegetable of every atom of its moisture, and turn every known animal to dry bones, but would speedily turn the surface of the earth itself to ashes, or make it assume that most singular aspect of the scoriæ of some vast furnace, which we observe in the airless and streamless, and therefore the plantless and the tenantless moon.

In like manner, if the level light, which is the very maximum of obliquity, were to fall constantly upon the poles—and the dispersive power of the atmosphere would bring it to a considerable distance around the mere poles themselves—though there would be twilight, there would be no action of the solar heat; and therefore there would be no stimulating agent to call forth the principle of life in an animal or a vegetable, and nothing which could deliver water itself from the fetters of ever-during ice. But it is no part of the bountiful law of creation that any one part of nature shall either work or lie dormant to the final extreme. In the utmost of its practical intensity, whether in respect of fervent heart or freezing cold, or of any thing else, the reins of mercy are still in the Almighty's hand, and there *is verge* and scope enough for going a *little farther or* a little faster, if those mysterious

workings of the system which we cannot understand, because we cannot analyse them into all their particulars, shall render it necessary.

And the simplicity with which this is brought about, is a matter of perfect astonishment, as well as of great delight. The plane of the orbit in which the earth performs its yearly round, makes an angle of twenty-three degrees twenty-eight minutes; or a little more than a quarter of right angle, or angle made by two lines when one is perpendicular to the other, with the axis around which the earth performs its daily rotation. In consequence of this, the sun tells, in all his influences upon the north pole and polar region of the earth, during one half of the year, and upon the south pole and polar region during the other. By this means, the intensity which would be produced at the equator, or circumference midway between the poles, by a continually vertical sun, is broken down and distributed over the surface of the globe; so that during the one half of the year it comes down more than one fourth into the one hemisphere, as divided in the equator, and during the other half of the year it alternates in the same way into the opposite hemisphere.

In consequence of this very simple arrangement, there is not only a distribution of the solar energy over the globe of the earth quite different from what there would be if the axis were at right angles to the orbit; but there is an alternation, not only between the two hemispheres, but between the heat and cold, or summer and winter, which alternate in each hemisphere in different times of the year, and which, by producing as it were a *double degree* of the mean cold at one season,

obtain a double degree of heat at the other. In respect of solar intensity, the maximum as to effect is thus brought nearly to the same degree in every latitude; and the difference is thrown upon the time for which this energy lasts during the course of the year. At the equator, it does not, if the circumstances and situation of places are the same, vary much during the whole twelve months; while near the pole it is reduced to a month or two in the summer, and during these the sun is in the high latitudes, constantly above the horizon and shining. Yet, under this perpetual sunshine there is upon irregular surfaces an alternation which in respect of temperature bears a resemblance to day and night, or even to summer and winter. The sun is constantly present, but his light comes oblique and slanting, and the shadows of objects are consequently long, just as they are immediately after sunrise and just before sunset. The shadows too partake of the nature of that cold twilight which we have mentioned as the necessary result of any oblique sun-beams; and the consequence is, that while the sunny side of an elevated object enjoys a heat equal to the average at the equator, the shadow side may be as cold as winter; and those who resort to the Greenland seas for the purpose of catching whales, often observe the pitch, which remains hard during ordinary summer days in this country, running down the sunny side of the ship as a liquid, while in the shade the moisture of the human breath is instantly converted into ice.

Between the extremes—namely, the regions of the equator and those of the poles—there is, unless in so far as it is *modified* by local causes, a gradual passage *from the one* to the other; and the innume-

rable varieties of the character of the year, and consequently of the vegetable production of the year, are the natural results.

The hemisphere which is heated draws the air of the other hemisphere to it, just as the heat of a fire draws the cold air of a room toward itself, and after its purpose is served, sends the remainder up the chimney, to be again cooled without the house; and, as this takes place in the one hemisphere the one half year, and in the other hemisphere the other half year, there is a transfer of the atmosphere over the regions of the equator northward from our spring to our autumn, and back again southward from our autumn to our spring. Some circumstances in the physical condition of the two hemispheres, the particulars of which are too extensive for our attempting to explain them here, but the chief of which is the great excess of sea in the southern hemisphere, causes the atmospheric motion from the south to produce violent rains in the tropical countries, which rains alternate with equally intense drought during the remaining portion; and these wet and dry seasons, which are single in some countries, and double in the course of the year in others, owing to different local circumstances, are the seasons of growth and repose for tropical vegetation.

The alternation at the poles is that of continual day with heat at one time, with continual frost at another; and during the latter the ground in high latitudes is covered with a mantle of snow, which prevents it from becoming so cold as it would be if it were exposed bare to the chilling influence of the sunless atmosphere.

These again constitute the seasons of activity

and repose for the vegetable tribes, in the polar regions; and as the heat of summer is brought up to its strength thus only by being shortened in its duration, the period of vegetable activity is, in those regions, much shorter than that of repose.

In the middle latitudes the two seasons as affecting vegetation partake partly of the tropical and partly of the polar character; and in proportion as the situation is nearer to either of those extremes, the character of that extreme predominates the more. In such countries both turns of the atmosphere produce rain; and about the middle latitudes that rain is thrown nearly into the middle of each half of the year, and becomes a summer rain in the one and a winter rain in the other; but generally speaking it is, over those regions, a spring rain and an autumnal rain; and the atmosphere is more tranquil during the middle of winter and the middle of summer, than it is at other times; the one period consisting of an interrupted drought under a clear atmosphere, and the other of continued frost or snow upon the ground, under an atmosphere equally cloudless, saving the fogs which arise from the daily changes of atmospheric temperature, and the monthly variations of atmospheric tide which are produced by the moon.

But it must be understood that in the temperate climates the distribution of the year into those two seasons, and the modifications of those seasons, are produced not by one cause, or by two consenting causes, but by two opposing ones; and near the middle of the quadrant, where those causes are nearly equal, the balance between them must be most easily disturbed by local circumstances; and *consequently the* seasons then must be much less

uniform than they are either in the tropical regions or near the poles, and must also differ more with the physical differences of the earth's surfaces.

The above paragraphs present only a very brief outline of those general causes which affect the growth and the repose of vegetation, on the different parts of the earth's surface; and they apply only to the average, upon the supposition that the surface is perfectly uniform. But this is all which is absolutely necessary for a general understanding of the principle; and the details must be sought for in the observations which have actually been made at the different places, the published accounts of which are the only abstract from which any individual of the human race, however desirous of obtaining knowledge, and however diligent in the acquiring of it, can learn the details of this very extensive and instructive volume of the mighty book of nature. Let us now see how the general kinds of seasons and their causes, upon which we have thrown a hasty glance, will assist us in understanding the adaptation and economy of vegetables in the several regions alluded to. We shall begin with the region of the poles.

In the most remote of these, the summer is so very brief, that few seeds have time to germinate, rear their stems, expand their flowers, and again ripen the succession of seeds, before the frost again returns. Hence there can be but few annual plants, which flower and produce seeds; and at the extreme limit of vegetation, when the frost is off and on with the alternations of light and shadow, there can be no flowering plants, nor any plant, but such as is almost without organisation; for there is no length of time in which an organisation of

any complicated structure can be formed; and it is a law of the whole vegetable creation, that if the organic product of a season of action, whether it be a whole plant from a seed, or an extension of substance in a old plant, must be perfected before the season of repose comes on. If it is not so perfected, then there is no perfection for it, and it must perish as an untimely thing. This is a consideration which it is absolutely necessary for us to take along with us, in every inquiry concerning the action of vegetables, if we wish to conduct that inquiry with understanding.

A very little personal observation may suffice to convince any one of the fact that every vegetable production must be completed in a single season of activity, and before the period of repose comes on. For we have only to look at the effects of a slight return of winter for a single night, or even for a single hour, after the spring has made considerable advances. We find that it not only blights the blossom, but withers the leaf, and turns the young shoot to an unprofitable excrescence, to be cast off from the part of the plant which had been matured in former years. But, if the same shoot enjoys genial weather during the time of its growth, and after that is ripened and consolidated by a wholesome autumn, then the utmost severity of the winter hurts it not a jot.

This, by the way, is the reason why the spring is often more precarious, and vegetation suffers more in moderately warm countries than in those which are much colder. The opening spring, which is the time of contention with winter, is protracted in those countries; because the solar energy of the year is, as it were, young and feeble; but when the

winter has a more powerful hold on the general character of the year, a considerably longer time must elapse before the energy is sufficient to overcome this winter; and thus vegetation starts more rapidly into growth, and is more secure while growing, in the polar parts of habitable countries than in the middle of the temperate latitudes, though the time of its commencement is much later in the year. In many places of Russia, of Sweden, and of Canada, it is generally winter the one week and summer the next; and sometimes the transition from a mantle of snow to a carpet of leaves and flowers is produced in eight-and-forty hours, or even less. It is the same with the alternations of drought and rain in tropical countries, as it is with those of cold and heat in countries near the poles; for in both the greater the maximum difference between the characters of the two seasons, the more rapidly the transition from the one of them to the other is made: and in many parts of such countries, every herb will be withered, and the earth like iron under the foot, when one retires at night; but during the night the turn of the season may come, and the rain-flood may be poured on the heated earth in an absolute sea, and before the observer can again quit his dwelling, and view the face of nature around him, he may find an Eden where he left a desert, though one brief week ma hardly have elapsed.

It is necessary to take this other case of the di ferent degrees of rapidity with which vegetab work under different circumstances along with if we would understand the uses of the seve parts and modifications of parts in different ve *tables; and if* we do not make ourselves acquai

with those uses, the pointing out of differences and the giving of names to them, are time thrown away and words wasted.

The power of vegetable life is in itself a passive power—that is to say, it could never, of itself, singly evolve one organ, or part of an organ, any more than it could create the substance of a plant out of nothing; and, indeed, the supposition that it has this active power in itself, though very frequently admitted by those who look at matters superficially, is, in truth, the very same as saying that the plant is self-created. It is the general action of the year, in which many agencies combine together, which stimulates the seed, and also the plant which is in a state of repose; and when the stimulus which nature has appointed is applied to a seed in one case, and to a plant of even a hundred years' standing in another, the action of the two, which results from the stimulus telling upon the faculty of being stimulated, is not different in kind. It is only the difference between an earlier and a later stimulus. That of the seed is the first time in the case of the individual, but in the old plant it is the hundredth time in the case which we have put. It might be an acorn in the one case and an oak in the other; and then each action would be one year's growth of an oak; and all the differences would be merely those of size and time.

Now, as the plant must in every case be raised by this stimulus, and as the stimulus varies in the manner which we have mentioned, the adaptation of the plant must vary in exactly the same proportion, in order that nature, though working *differently, may* work equally well on all places on *the earth's surface* which are adapted for vegeta-

tion. If the growth of the awakened plant is to be sudden, it must have a corresponding provision for that growth; and if the growth is to be slow, the provision must be moderate. All other variations must harmonise with each other in the same manner; and there is also required a counterpart to this harmony—namely, that the means of protection shall be sufficient for securing the life of the plant during the period of its repose; for we are to recollect, that while the plant rests during the drought or during the cold, it must still possess the faculty of being acted on when the stimulating cirstances come, or else it ceases to be a plant, and belongs to the category of dead matter.

The plants with a single cotyledon are, perhaps, the best in which to take the application of those principles; because they constitute the greater part of the general carpeting of the earth; and are, perhaps, considered as a grand division, fully more active than those with two cotyledons; and thus they must vary more in the modes of their production in different latitudes. We shall, however, notice them in a new chapter.

CHAPTER IV.

PRODUCTION AND GROWTH OF PLANTS HAVING A SINGLE COTYLEDON.

In noticing those organs in the plants with a single cotyledon which adapt them to the seasonal action of the different latitudes, we shall confine ourselves chiefly to the annual growth, whether in the germination of the seed, the evolution of a new

plant from the root, or the elongation of a stem by a terminal bud; as these are the chief modes in which the action of such plants is exerted. A considerable number of those plants are strictly annual—that is, they must be raised from the seed during every succession; but there are many of them which can last for a part of the winter, but still they do not hybernate, or pass into a state of absolute repose, though their action may be slower. Plants of this kind are usually very productive of seeds; and the seeds of most of them are invested in firm membranes, and capable of being kept for a considerable time without losing their power of germination. The grasses, including the grain plants among the rest, are familiar illustrations of this; and they are convenient as every one has ready access to them. The germination of the seed depends on a certain state of heat and moisture, which brings on a sort of fermentation; and this fermentation, if the heat were raised sufficiently high, and long enough continued with a sufficient supply of water, would convert the farina or starchy matter of the seed into a sort of sugar. This substance is not the germ of the plant, but merely its more immediate stimulant, and also its nourishment, until it has acquired or elaborated organs for itself. The germ of the plant is a small body, formed by the union of the coats or tunics of the seed, and seated immediately within these coverings. This is called the corculum, or little heart; and even in its rudimental state, it is a compound body, consisting not only of organs, but of the two parts of the future plant, the seed and the root; and those two parts are distinct from each other, even when they are not distinguishable by our observation.

What power of development then may be in those two parts of the germ, and whether each does or does not carry along with it the function of the other, and could elaborate organs for it, and exercise those organs under favourable circumstances, are points upon which we cannot positively decide. In such matters our actual knowledge cannot go beyond our observation; and the case of an individual plant, we never see the beginning—the first rudimental of the corculum; neither do we see the end, that is, we are unable in any case to say, that the seed which produced any one individual plant could not, under different circumstances, have produced one of more ample dimensions and more fully developed. Thus, for instance, one grain of wheat, placed in an unfavourable soil, and exposed to an inclement atmosphere, may send up only one dwarfed and feeble stem to the height of an inch or two; while another seed taken from the very same ear, and more favourably treated, may send up a dozen of stems, each of them attaining the height of six feet or upwards. But there is always one point upon which our knowledge is certain, and that is, that the specific character is transmitted from the parent, in the formation of the germ, and from that character the young plant cannot deviate, how different so ever its development may be under different circumstances. It so happens, that in many plants the portion which is elaborated as stem can be made to produce roots; and the roots can in other instances produce new stems; but still, in none of these changes is there the least deviation from the specific character. For whatever may be the change *in the development*, the part is always the part of

that plant, and not of another; and though in the instances which we have mentioned, stem and root are made to alternate with each other, yet a stranger, or that which is found belonging to a plant of a different species, is never, in the regular course of nature admitted into the succession. Even the true roots or rootlets, which are understood to be the organs by means of which the plant receives its nourishment in the ground, are not capable of being changed into stems; and therefore, the parts which are called roots, which have this faculty, are really underground stems; and, generally speaking, when they produce a new stem rising above the surface of the ground, they at the same time produce new roots for the nourishment of that stem.

Plants which have this last-mentioned power, are always of longer duration than annual, even in cases where the individual stem does not last out the year; and this mode of production sometimes takes place by an extension entirely under the surface of the ground, as is the case with perennial grasses, and with many of the ferns, and other plants, and sometimes it extends along the surface, taking root at certain distances, as may be seen in the runner of a common strawberry. When roots are put out in this way, and produce new plants, they are always put out from what may be called the crown, or coronal plane of the plant from which they proceed. This plane is the line of distinction in the individual plant, between what is really stem and what is really root. In some instances it can be readily distinguished by the eye; but there are others in which it has no visible sign; and therefore its existence is only inferred; but there is no *doubt of the truth of* the inference. Sometimes

again, the plant has not only the power of multiplying itself by roots in this manner, but actually producing young plants as well as seeds, on the elevated stem, or of retaining the seeds on the top of the stem, till they have germinated, and acquired both roots and leaves, so that they drop from the parent plant in the state of little plants, fit for carrying on their functions independently; and where this is the case, the old stem and also the roots which nourished it, die away as soon as the young ones are matured.

The roots of which we have been hitherto speaking, belong to those which in the greater part consist only of fibres in the true root; and in this case, that true root, however it may continue the succession, is only an annual. Therefore, they are best adapted to those countries where the temperature is compatible with something approaching very nearly to a perpetual growth; and consequently this is the character of surface vegetation in the temperate latitudes. Our grassy meadows and pastures are examples of this description of vegetation; for, if there is moisture enough, and the weather is never too cold, the perennial grasses on such pastures continue their multiplication by their roots all the year round, while their production, by means of seeds formed at the top of the *culm* or stalk, is only seasonal.

Plants of this habit are not so well adapted either for tropical climates or for polar ones; and hence, in both of these, the grasses are few, and we meet with none of that soft green sward which is so pleasing to the eye in temperate latitudes. The reason is, that both the tropical latitude and the polar one are too violently seasonal for admitting

of the perennial action and perennial increase of the plant, by the continual growth of the roots; and thus, the whole production of such plants is there confined to that by seeds; and in either latitude, if we were to suppose a crop of perennial grasses to be brought on the surface artificially, and then left to the operation of nature, without any artificial treatment by man, this crop would soon disappear from both, and each would become covered with a vegetation better suited to its physical character.

Many of the perennial grasses have, however, a power of extending runners under ground, and forming roots and the incipient stems of plants at nodes or joints of those runners, without sending up any leaves or stems to the surface. This often happens with the creeping grasses of our own country; for when the surface leaves and stems are burned up by violent drought, which comes suddenly—and therefore does not dry the ground to such a depth as if it came less severely but continued longer—it will be found upon examining the ground, that the sod is full of these runners, which keep making roots, advancing in length, and increasing in consistency, until the earth about them is perfectly dry. When the drought is of such continuance that it reaches them, it will be found too, that there has been a sort of ripening of those runners, and that they will bear drought for a considerable time without losing the properties of growth, and many of them are sweet to the taste, and would, if cleaned, make excellent stall provender for cattle.

Grasses of this description are by no means the chief favourites, even with graziers in such countries as Britain, though there is always now and then some projector who introduces one as a

most valuable grass, and puts the cultivators first to some expense in getting this grass into their fields, and then to a great deal more in getting it out again. In India, however, and in various other tropical countries, where the great and long continued heat renders it impossible to grow kindly grasses above the surface, the people are often obliged to substitute their ground crop; and a man will go out with a rake, and after plying it for a short time in a field apparently without the least vegetation, he will return loaded with a bundle of no contemptible hay, consisting of the sort of runners to which we have alluded; and often so rich and sugary, that it might serve for human food, as well as the seeds of some of the coarse cereal or corn grasses, which are grown in those dry and burnt-up places.

But in all those means of the propagation of plants to which we have yet alluded, whether by seeds, or by an increase of creeping or extending roots, there is but a moderate provision for the succession plant, not greater then there is in that bud upon a tree which is to produce, or be developed into, merely a twig. Still, there is something to be learned in the matter; wherever the plant has the double mode of production, we can, in our artificial treatment of it, work it upon either part of the mode, and according as we do so we can have that increase which is the object of our culture, either in roots and surface leaves, or in seeds; and we cannot adduce a better instance of the contrast of the two, than a well-clad and close-browsed meadow, and a clean and healthy wheat-field by the side of it.

We have noticed already that the extent to which

any seed can develope itself, or rather the extent to which it will obey the stimulus of natural action, is unknown to us in the volume of growth which could result; and it may be added that we are just as ignorant in respect to the length of time that the energy could be made to continue. And this extent of time is the real distinction between an annual plant and a perennial one of any of those kinds to which we have alluded in illustration. The production of seed is, as already explained, the unusual action of the plant, and the production by extension of the roots is the perennial action, and depends much more upon soil and climate than upon season. Therefore, though we have no certainty in the matter, it is highly probable that annual cultivations may, if continued long enough, produce an annual habit, by so diminishing the the tendency to perennial growing as to make it unable to react, especially in soils which have been reduced to a mould by artificial working. It is probably in this way that the whole of the corn plants which have been cultivated for human food have been made annuals; for such of them as have the property of tillering, or increasing by additional stems at the root in the same crop, make at least one approach to the perennial action; and they sometimes make another, by a sort of succession from the roots when the first production has been injured in an early stage.

On the other hand it seems highly probable that by repeated working, though the mode of working is not so obvious here as in the other case, the perennial mode of production might be strengthened in *many of* the annual plants—if such a *change were rendered* necessary. The next species

of additional production in plants with a single cotyledon in the seed, is that in which there is a specific provision for the succession plants in a distinct organ. This organ is either a bulb or a tuber, of the one of which the onion is an instance, and the potato of the other. But connected with this there are some modifications of plants in which the seed, at least under some circumstances, first produces an enlargement, and after a very great enlargement of the root, and then this enlarged root evolves a new stem, which in its turn produces seeds. The carrot and turnip, and very many of those plants, the flowers of which have four leaves placed in the form of a cross, are instances of this mode of production. But though there are two seasons of growth in a plant of this kind, it is after all only an annual; and several of these plants show the annual habit by flowering the same season that the seeds are sown, even when they are cultivated artificially. In the natural state, many of those plants have much smaller enlargements of the root than they have when cultivated; and there are some in which the whole production is annual, and the root perishes the same year that the seed which produced it germinates. Indeed it is still a general law of those plants that the root which has produced a flowering stem and ripened its seed, does not produce another, but speedily perishes. There are no means of multiplication in the root of those plants, generally speaking, so that a new plant is never obtained from one of them; and therefore the fact of having the root small and dying in the autumn, and having the root large, and lasting through the winter, to flower and bear seed in the early summer, and then to perish,

appears to depend much more on external circumstances, than on any thing essential to the physiology of the plant.

There is a considerable difference in the mode in which the pulpy matter, which shows very little of a fibrous structure, and which is therefore understood to be more particularly the store which the plant prepares as the material of its action of fructification, is situated. In many, as in the whole of the *brassicas*, comprising the cabbage, the turnip, and many others, this pulpy matter is accumulated internally, not only of the rind and bark, but of the fibrous part of the stem, which fibrous part in the stems and roots of many partakes a good deal of the character and consistency of wood. In all the cabbage tribe, especially such of them as have stood the winter, and are preparing to send up flower-stems in the spring, there is always a large accumulation of this matter, forming a large mass in the centre of the stem, and sometimes bulging it out, till it has the appearance of something like the bulb of a turnip above the surface of the ground. In the carrot again, and in various other roots, the accumulation of pulpy matter is external of the fibrous part, and constitutes that portion of the root which is darker in the colour and more agreeable to the taste than the portion which it covers. But, whether the great accumulation of this matter which is to support the plant in its grand labour of flowering and fruiting, be internal or external, the purpose of it is always the same, and it is collected and disappears under circumstances exactly similar in all the varied case. If the plant is to flower in the same season, or time of continuous growth *during which the* seed germinates, then the accu-

mulation does not take place; but the matter elaborated by the plant, is applied to the production of the flower stem, the expansion of the flowers, and the maturing of the seed as fast as it is elaborated. Thus, whenever the seed is ripened, and ready to be cast upon the earth, there to produce a succession crop, the old root, having performed its final labour, that of transferring the principle of vegetable life answering to its species, to a perfectly formed seed, falls into decay. If, however, the flower stem is not produced during the first season of growth in the plant, or if being in the course of production it is removed at an early stage without injury done to the leaves, then the plant immediately begins to prepare for flowering and producing seed in a future season, by accumulating in the root that matter which its vegetating power assimilates, above what is necessary for the growth of the leaves, which are now the only parts above the surface of the ground. Nor is it unworthy of remark that, if the production of leaves is more than ordinarily great, the bulbing, or production of matter in the root is proportionally small; and this holds in the case of tubers, such as the potato, as well as in that of the bulbous roots, of which we are now speaking. This fact holds out some important lessons to the cultivator who rears those plants for economical purposes; if he wishes to have them with large bulbs, he must not cultivate in too retentive and dry a soil, because in such a soil the great production of leaves will rob him of that part of the plant upon which he sets the highest value. Hence, cultivated plants of this description succeed best, and are most profitable to the grower *on light soils*, where a good deal of rain falls, but

where, in consequence of the porous nature of the soil and subsoil, the water does not stagnate about the roots, but merely moistens them, and then passes off. This is true of almost all plants which form at the root a store of nourishment for a future growth, or even which produce succession plants there, which last is the habit both of the true bulb and of the true tuber. Those under consideration are not, strictly speaking, bulbous-rooted plants, they have merely the faculty of producing a greater enlargement of the root, beyond what is necessary either for the support of the plant or for the nourishment of that part of it which is in present action above the surface of the ground. In most instances, however, those enlargements are really of the root, and not of the stem; for the coronal plate or collet, which forms the division between root and stem, is on the upper part; and when the plate is cut off, the remaining part of the root, though it contains by far the greater portion of the substance, is incapable of any future vegetable action. In most species, too, though the larger leaves perish more or less entirely, according to the severity of the winter, yet it requires that there shall remain upon coronal plate or crown of the root, the rudiment of a stem, however minute that rudiment may be, otherwise there is no fresh action in the plant when the season of growth returns. Sometimes there is only one such rudiment in the plate, and sometimes there are several, which last occurs chiefly in those species which generally have lateral buds in the stem. In all cases however of plants of this description it should seem that the rudiments of all those stems which *are to* be developed and to flower *during the early part* of one season really belong

to the growth of the preceding season; and that it is only in consequence of late sowing, or otherwise a short period of action, which makes them produce a store in the root, instead of elevating their flower stems and perfecting their seeds in the same year that they are sown. It is worthy of remark too that the enlargement of the root begins to take place nearly about the same time that those plants of the same species which were to perfect seeds in the first season, begin to send up their flower stems; and that the root, generally speaking, receives its greatest enlargement by the time that the completed plant has matured its seed, and begins to decay. The enlargement of the root may be supposed however to continue a little later in the season than the action at the top of the stem; for while that is advancing and vigorous, it is much more exposed to the stimulative energies of the atmosphere than the root can be, as the latter is shaded by the leaves from the light and heat, and sheltered by the same from the free influence of the winds. On the other hand when the weather becomes cold, the leaves become a shelter to the root; and by this means its action is protracted to a later period. We find a very striking illustration of this in turnips, which have their enlarged roots differently situated. If they are almost wholly above the surface of the ground, the leaves are smaller and the bulb grows faster and generally attains a larger size, than it does when more deeply seated, and shaded by a more ample foliage. The farmer is well aware of this circumstance, and often turns it to very considerable account.

We have noticed those plants which have en-

larged roots in this chapter, and along with the bulbous-rooted plants, because, in common language they are not unfrequently confounded with each other; but it is necessary to bear in mind that they do not belong to the same division; for all those plants which have enlarged roots of the form now described have two cotyledons, whereas the bulbs properly so called have only one. We may mention farther, that these plants which have the roots more or less enlarged according to circumstances, are, like the grasses, best adapted for temperate climates, and even for the portion of such climates which are not over warm. Very severe heat accompanied by drought would destroy the rudimental stems on the crowns of the roots. Very severe cold would have the same effect; and we frequently find that keen black frosts, that is frosts unaccompanied by snow, destroy those plants. If however a protection of snow is brought upon them before the frost becomes very severe, they are safe; and therefore in a state of wild nature we find plants of this description growing well where the winter snow comes on early, and remains undisturbed till it is almost instantly followed by warm weather.

Bulbs properly so called, are without exception plants having one cotyledon; and the enlargement which takes place in them is not in the root, but in the stem or the leaves, for most of them have no true stem, except that which rises to support the flowers. In them the coronal plate to the root or root-fibres, the organs by which the plant draws its nourishment from the earth, is a radical plate in respect of the bulbous enlargement, whatever *this enlargement* may be. It must be admitted

that the difference or actual situation between the radical plate of the bulb and the coronal plate of the enlarged root, is one of expression rather than of reality. The enlarged portion, whether above the plate or below it in the order of growth, is the part of the plate to which our attention is more especially drawn; and the only difference with regard to position is, that we call the plate the crown or top of the enlarged root, because that root is below it; and we call it the base or bottom of the true bulb, because in the natural position of the plant that bulb is above it.

There is, however, a remarkable physiological difference between this plate in the two kinds of plants; for it seems to partake much more of the nature of a stem in the bulbous plant than it does in the one with the enlarged root; and though the bulb as well as the enlarged stem often contains an abundance of nutritious matter, yet this store is not directly elaborated by one stem working in the air, and afterwards dying down to a mere rudiment which is to exhaust in flowers and seeds the matter which it had assisted to form in the preceding stage of its growth. The plate, or collet which may be used as a general name for the two, is also a much more distinct organ in the bulb than in the enlarged root. In the latter, the line of distinction between it and the stem and leaves is generally pretty obvious, at least around the circumference, where the cicatrices left by the leaves that have peeled off, give it a peculiar wrinkled appearance. On the other side, however, it passes so gradually into the substance of the *enlargement*, that the one cannot be distinguished *from the other*. In the bulb it is different, the under

side is generally nearly flat, and has the fibres or root attached to it; while the upper side is more or less thick, and the entire organ has the form of a convex button. The under side of this collet or button is capable of producing nothing except the fibrous roots; but there is a very different power in the upper side, or rather, perhaps, in a certain portion of the substance. It gives origin to the leaves, whose enlargement at the basal part forms the mass of the bulb, and which, when the bulb is excited to that action which is to produce the flower, rise above the surface of the ground; and in the centre, or somewhere among these leaves, there is the rudiment of the stalk, which is to produce the flowers. In addition to this, however, there are distributed among the bases of the leaves, and originally contained in the substance of the collet, other rudiments which are not to produce flowering stalks only, but which are to evolve new bulbs, either within the old one, and occupying its place after it wastes away, or issuing laterally from it and forming what are called off-sets. Sometimes those off-sets have their radical collet almost forming part of that of the parent bulb, or at all events so close to it that they appear to be in union; but in other cases, the off-set is nourished by an umbilical cord of considerable length, which cord conveys nourishment from the old bulb to the young one, until the latter has made such progress as that it is capable of drawing its own nourishment. In this last case there is an approximation to the tuber properly so called, which is in most cases connected with the parent plant by a cord of this kind; and it is worthy of remark that, in *all these cases of* production, it is never tuber

directly producing tuber, unless there has been previously some production of a plant upon the tuber, though some external circumstances often cause this production of a plant between one tuber and its successor to be so minute as almost to escape observation. When circumstances are such as are usually understood to be most favourable to the whole action of the bulbous plant, both below and above, the umbilical cord at the extremity of which the new tuber is formed, and which indeed often branches so as to produce a number of tubes, always issues from what is to be regarded as the coronal plate of the parent plant; that is, from the union of the stem with the fibrous roots which are the organs of nourishment. It seems, however, that, as is the case in the bulb, the coronal plate of the tuberous plant partakes much more of the properties of stem than those of root; and it is probable that in these plants, as well as in all plants which can put out branches and bear fruit at the joints or other parts of the main stem, this productive power of the plate rises with the stem, and a portion of the stem requires nothing more than being earthed up in the ground, to make it produce umbilical cords and tubers, instead of leaves, stems, and fruit. We have an example of this in the common potato; for if a single plant has sufficient space in ground well adapted for it, and the stems are judiciously earthed up, they may be made to produce tubers at many joints, which, if left in the air, would have produced nothing but leaves and flowers; and the increase in such a case is always greater than if the plant is prevented from flowering.

Bulbous and tuberous plants are exceedingly

numerous, many of them are highly nutritious, though others have qualities very opposite; and some of them are among the most splendid in their flowers in the whole vegetable kingdom. But the descriptions and details of the genera and species are subjects only for the professional botanist; and there are many single families of those upon which a dozen of large volumes might be written, and still very many interesting particulars necessarily passed over unnoticed.

As we mentioned in the case of the grasses, whether of the annual ones which tiller, or produce a number of stems, which come to maturity nearly about the same time, or of those perennial ones which grow by extensions of the roots—as we mentioned in the case of them, that we knew not the extent to which the productive power might be carried, so also it is with all bulbs and tubers having a power of increase. The bulb may bring forward only one flowering stem in a season; it may bring forward an indefinite number, or it may perfect none. So also it may produce in the same season an indefinite number of off-set bulbs, or it may produce none at all. It may also, if not stimulated, and yet not exposed to any destroying cause, remain unproductive for one year or for several years, and yet be at the end of that time capable of being stimulated into as vigorous action as if it had begun to work immediately when matured. It is the same with the tuber; it may multiply greatly in new tubers, or it may produce none at all, even though in the latter case it may flower abundantly. Indeed, both in bulb and in tuber, excessive flowering and fruiting is always accompanied by a diminished production at the root. In

the same manner, too, the bulb or the tuber ca
carry on its underground production, at least to
certain extent, without the usually accompanyin
action of rising and flowering in the air. This las
mode of increase often occurs in the commo
potato, where intense drought, destroying the stem
before the fruit is ripe, brings on a prematur
ripening of the tubers. In such cases the tuber
put out umbilical cords, and those cords produc
little tubers, which do not come to perfect maturity
but by the production of which the quality of th
original ones is very much deteriorated.

Finally, to explain all the modes of action
those highly interesting plants would require n
common extent of writing; but the few particula
which have been enumerated will, it is hope
engage the attention of the common reader, an
also prepare him for understanding to what regior
of the world, in respect of climate, those plants a
best adapted. From the position which the coron
plate, the essentially vital part, is situated in th
bulb, it will be seen at once that the chief prote
tion which the bulb has is against drought an
heat. Not only that germ which is in progre
for flowering, but the successional germs which a
to be evolved one after another, are encased in th
thickest leaves which form the bulb; and tho
leaves are of that succulent nature and have th
smooth epidermis which characterise those plan
that can best endure the long protracted and bur
ing heats of the thirsty desarts. On the oth
hand, we find that there are comparatively fe
bulbs which can bear to be soaked in water,
exposed to severe cold. Hence bulbs form a mo
prominent part of the vegetation of tropical cou

tries, and of the warmer places of the temperate. They are, in fact, the lilies of the field, to which Solomon in all his glory was not like, though the most splendid of these are found in countries which were not known, and therefore these plants could not be alluded to as illustrations suited to the capacity of the people, at the time when that portion of the sacred volume was written. The plains of tropical America, of Southern Africa, and of various other tropical countries where the seasons of drought and rain alternate with each other, are the homes and head-quarters of those splendid plants; and the contrast which they make between the dry season and the rainy, is such as never fails to astonish any inhabitant of temperate climates who visits them for the first time. Only a few days elapse till those bulbs which were latent during the season of extreme drought, send up their stems in all their vigour, and expand their blossoms with a glory which no production of temperate climates can rival, although some of the bulbous-rooted plants of these are among the most exquisite of their productions. Nor is it in the soil alone that we find those splendid members of the vegetable kingdom; for in the wild forests there are many species which are never rooted in the ground, or in places of the trees which accumulate soil, that rival, if they do not exceed, any other of the products of the vegetable kingdom. No doubt it is only in the hotbeds of nature that those splendid plants make their appearance, but wherever they appear, it is impossible to refrain from admiring their beauty, and very often their fragrance is equally admirable. Many of the plants which, having their bulbs in the air, *or merely reposing* upon supports of trees, in Brazil,

Guiana, and other rich districts of central America, are exquisite; and they are not more exquisite than they are useful in the economy of nature, for they chain the forest trees together, so that when the hurricane overtakes them, one cannot be overturned without carrying the others along with it; and thus do those climbing plants, which are usually set down as being parasitical around which they climb for their support, really contribute a great deal to the stability of the forest which but for them would be uprooted by the violence of the winds.

Most of these *Epiphyteæ*, or plants which grow suspended upon, but not as is sometimes supposed parasitical or draining the juices of, trees, belong to the family of the *Orchideæ*, of which there are various British species, and some even on the slopes of the Grampian mountains. With us they are annual plants as appearing above ground, and they are bulbous rooted—a new bulb being produced every year. Of our species, it is remarkable that those which grow in rich and humid ground have a rank and offensive smell; but those which grow on the sterile heaths have a very delightful fragrance. Ours are a mere specimen of this most curious and delightful family of plants, and a specimen as humble and as far below the average as can well be supposed; but in the regions to which we have alluded we find plants of this family, of which no language can adequately express the beauty. In the eastern islands, and in that peninsula of Asia which lies to the eastward of the Bay of Bengal, there are some of the most delightful species. Of these we may mention *Renanthera coccinea*, which climbs to the tops

of the highest trees, produces flowers in vast abundance, and in large and elegant bunches; so that the whole forest, without any injury to the trees which afford support to those plants, is clad in a mantle of the most brilliant gold and the most intense scarlet; nor is this all, for when the dew of eve is forming, and the aroma which the flowers give out is arrested by the humid air, the sense is taken captive by the perfume, and all that fable ever feigned of "Araby the blest" is more than realised by this most delightful native of the east. And, as if in order to show that the very choicest gifts of nature are within the power of man, and actually prepared for his use, this delightful plant readily obeys the hand of the cultivator; and the Chinese, who take more delight in ornamental plants than perhaps any other nation on the face of the earth, train it round the cornices of the rooms, where its beautiful flowers hang in festoons half way down the sides, retaining their beauty in full perfection for a month or six weeks, and giving out in the evening and during the night an odour which defies imitation by the most skilful perfumer. This odour, too, is not, like the odour of many plants, injurious to the health. It is slightly, but very slightly, narcotic; and the sober Chinese, after the close of his labours and the refreshment of his tea, retires to a chamber replete with this odour, and falls into repose as though he were "lapt in Elysium." This delightful plant has been flowered in England. It long resisted the methods usually resorted to for obtaining flowers upon exotics in our hot-houses; but Mr. Charles Mackintosh, head gardener to the King of Belgium *at Claremont*, a most skilful and enthusiastic cul-

tivator of the choicest glories of the vegetable kingdom, was not to be defeated. After trying various other methods, he covered the stem of the plant with moss, and kept it dripping with moisture; and it was not long till he was rewarded with a copious production of the most exquisite flowers. This plant is but one out of many of those children of the sun which enliven and adorn and perfume the tropical forests; and of which there is not a trace in the polar or even the temperate latitudes. We must not, however, imagine that on this account the Almighty is less kind to one place of the earth than to another; for every where He has set his signet, and his merciful goodness and protecting care are not less conspicuous amid the snows of the extreme north than in the exuberance of the tropical forest.

CHAPTER V.

PLANTS WITH TWO COTYLEDONS.

THIS may be considered as the most completely developed, or complicated in their structure, of all the vegetable tribes. The typical ones—or those which are more highly characteristic of their grand division, —are trees; but it also includes many shrubs, or trees of a smaller growth, and not a few herbaceous and even annual plants; but still, tree or herb, lasting for centuries or only for months, there is a common character which runs through the whole. The plants have in their stems something analogous to *pith, to wood,* and to *bark,* and though the period *of their duration* is in many species limited to a

single year's growth, that growth is distinctly exogenous. In this division, there is no multplication of roots, as there is in the former division; and the annual plant perishes, unless it is continued by seed; nor have we any instance in the whole of the *Dicotyledoneæ*, of the root producing a succession root, as we find in many of the plants that have but a single cotyledon.

But though the proper mode of reproduction among these plants is by seeds, this is not the only one. All which are capable of forming lateral buds in the bark, that is, between the bark and the wood —though the production of bud appears through the bark,—all which have this power, are also capable of being propagated by off-sets, or portions skilfully taken from the parent tree. They appear to contain, in still greater perfection, that property which we have already noticed as being possessed by some plants with a single cotyledon, of sending the coronal plate, or vital collet, through the working structure of the plant, in such a manner as that every part of it, especially those parts where there are nodes or joints, whether at the starting of a new growth, or at the production of a leaf, shall be endowed with the whole energy of the plant, and possess the double function of the collet—that is, one capable of producing either roots in the ground or branches and leaves in the air, according as they are placed in the one or in the other.

This is a very beautiful provision of nature in the case of many plants of this division; because it admits of their being multiplied in regions where their seeds do not come to maturity; and it also, in the case of many of them, enables a more speedy produce to be obtained, than could possibly be had

from sowing the seeds; because the cutting, the instant that it takes root, has the same development as it would have had if it had remained upon the parent plant; and by this means the plant comes much sooner into use than it would if raised as a seedling.

From the permanence of their duration, the plants of this character compose the characteristic vegetation of forests; and, according to the regions in which they grow, they give to the surface of the earth one of its most decided and striking characteristics. As they appear to the eye, and without going into the details of systematic arrangement, the trees of this class of plants may be separated into three grand divisions: first, those which are ever-green in the polar or colder regions of world; secondly, those which are deciduous, or shed their leaves in the fall of the year, chiefly in temperate climates; and thirdly, those which are ever-green, chiefly in tropical climates, but in the case of a good many individuals, in all climates whatsoever. When, however, we speak of an ever-green, to what part of the world soever it may belong, we are not to confound it with an ever-growing tree, which has the same action at all seasons; for, except in the case of some of these species which grow in water in warm countries, and which consequently know no difference of season, there is no ever-growing tree; and those species which have flowers, and young fruit, and ripe fruit upon them at the same time, which is the case with many natives of tropical climates, have pauses in their growth, as well as the deciduous trees which throw off their leaves, and remain perfectly inactive during the winter. The ever-greens of polar and other

cold countries, and of the cold and upland parts of tropical countries, may be said in general to belong to the natural order of *Coniferæ*, or cone-bearing trees. All things considered, it is probable that the coniferæ, with which, in some of the firs, every body is more or less familiar, form the best order with which we can begin. They are conspicuous in their size; peculiar in their form and colour, both in the leaves and the bark; and as they are, with very few exceptions, evergreens, they can be studied at any season. They mark the vegetation of certain spaces that can be traced for long distances upon the map; and they are generally accompanied with peculiarities in the soil, the climate, and the other vegetation, which render them a key to the whole natural aspect.

Their uses in the climatal economy of nature are, probably, greater than those of most other orders; and in value to man they are inferior to none. Length, straightness, stiffness, and lightness, are the characters of many of their stems; and, but for the coniferæ, it would not be easy to find even a tolerable mast for a ship of ordinary burden, or to construct a building of equal strength and durabilility without double the expense of masonry. Among them, too, it is possible to select timber which shall last as long as is wanted. Some are of so fleeting duration, as to be decayed in a very few years, even in climates which are not the most destructive to timber; while others appear to be proof to all the natural agencies by which that substance is usually decomposed, and yield to nothing but forcible mechanical division or combustion; and some of them resist the fire to a very wonderful degree. Some of them maintain their

green and growing state for several centuries, and and on that account, by nations so far apart as not in all probability to have borrowed their customs from each other, they have been, and are still, planted over the graves of the dead, as the fittest material emblems of immortality. The timber of some is of far longer duration: the funereal cypress has been said to last for upwards of a thousand years; and the cedar (probably the cedar of the Himalaya mountains, *Deodara*) for a very long period. The last-mentioned timber is, indeed, among the most indestructible of known substances. It is mentioned, that in some ancient structures in India, the date of which was lost in the distance of years, and the stone of which had yielded to the saline and sultry atmosphere, the bandings of deodara beams, with which the masonry was united, were as fresh and sound as if they had been newly fitted.

Though the coniferæ cannot be considered as one of those orders of plants upon which mankind mainly depend for food, yet they are not wholly useless in this respect. The seeds in some of the species, and the cambium in others, make in some parts of the world no bad additions to, or substitutes for, bread. The resinous secretion of very many coniferæ (which is, generally speaking, a compound of resin and essential oil), is, under the various names of pitch, tar, turpentines and balsams, of extensive use in the arts; especially in protecting timber from the action of the water, and in brightening its surface and protecting it from the air. The more minutely that we examine them, their difference from all other plants, and their general agreement *to each other*, become the more striking. With

the exception of the *Cycadeæ* (including among others the sago-plant,) the coniferæ are the only flowering plants of exogenous growth that have the seeds naked. By seeds is the only way of multiplying one important division of them, the success of other methods is precarious. At the same time there is not in the whole order any thing that can be considered as a perfect flower,—that is, a flower containing the fertilising and fertilisable parts. Nay, there is nothing which can, in very strict language, be called a flower at all, if a flower is to be considered as any thing more than a pollen, an overal or rudimental seed, and some sort of receptacles on which these are produced. The other parts both of the amenta, or pollen flowers, and of the cones (*strobili*) or seed-flowers, are scales or bracteæ of some description; and although in some of the cones these are hard and lasting, in the pollen-flowers they are generally of no very long duration. There are no calyx, no corolla, no stamens, no anthers, properly so called, no stigma, style, or ovary; nothing but scales, pollen, and seeds. It is true, however, that these are all that are essential; all, in fact, of which the use is known with certainty. About half the species used to be described as monœcious, and the other half as diœcious, but so far as they have been fully examined they are monœcious; and that renders it at least extremely probable that this character belongs to them all. But this character being merely one of form is not of much importance. It is probable that the notion of their being diœcious may have arisen from the fact that there is often pollen on the plant and no cones, or cones and no pollen. The vessels which contain the pollen (or, as

they are called, the anthers) are single, or in small clusters round a rachis or stem. Sometimes there are two lobes, sometimes more, and the anther is sometimes an undeveloped scale, for part of its length, or on the one side; but those variations are not of much importance. The anthers burst outwardly and discharge the pollen, which is often so abundant as to get the name of "brimstone rain." When the seed-bearing flowers are solitary, the external tunic of the seed sometimes forms into a pulp, as in the berries of the common yew. In the solitary flower the position of the seed is erect; but in those genera that have the flowers collected into cones, the envelopes of the seeds never take the form of berries, but remain naked, adhering to the scales, and in an inverted position. Each scale is separated from the one under it by a membranous plate or bractea. When the cone is young, and before fertilisation, these are coloured at their margins, there is an aperture between the bractea and the scale, and the position of the cone is often upright. After fertilisation, these apertures close, the scales become thick, the bracteæ are in some cases obliterated, in others they remain projecting from between the scales; in some genera the cones become pendulous, though in others they retain their upright position. As the seeds ripen, the scales become hard and ligneous in some, and tough and leather-like in others; and there are few of the species in which the scales open and the seeds escape till the cones have separated, and been for some time exposed to the weather. In the seeds the embryo is embedded in an albuminous matter, consisting of farina, with a greater or smaller admixture of resin and oil; when these (more especially

the oil, which has an acrid taste, and, generally speaking, a powerful effect upon the kidneys) are removed, which is easily accomplished by roasting, the farina becomes edible and nutritious, differing little in its nature from the farina of other seeds. In some of the genera, as the araucarias, more especially *Araucaria Brasiliana*, the resin and oil in the seeds are in so small quantity, that the seeds may be eaten without dressing; and such seeds are sold as nuts in the market of Rio Janeiro, and the other towns of Brazil. In others, again, the quantity of oil and resin (turpentine) is so great, that the seeds seem altogether resinous,—as is particularly the case with the seeds of the Indian cedar (deodara). In some, as in the common yew, there is a deleterious principle; and children have been poisoned by eating the berries, which are rather inviting, in consequence of their fine red colour and sweetish taste. It has been supposed that the poisonous quality is confined to the embryo, and that the albuminous matter and the pulpy tunic are quite harmless. Some eminent botanists are, however, of a different opinion; and certainly, the safe way is to avoid the berries altogether, as the pulp is neither racy nor nutritious. The embryo has its plumula to the base of the seed, and is furnished with opposite cotyledons, never fewer than two, and often in considerable numbers: but the embryo has a direct mammary connexion with the albumen. The cones are produced at the same time and place, as the branch buds; and the character of the plant is found in their structure. If the leaves (whether singly, or several in the same sheath), *are so placed* on the twigs, as that their *insertion can be* traced in a double spiral (that is, *a spiral toward* either hand) round the twigs, the

same character may be traced in the scales of the cones. Nay, the very same character extends to the branch of the tree, though there the regularity of it is liable to many contingencies. The branch may be destroyed in the bud; or the bud may never be formed, in consequence of inferior vegetative power in the side of the stem upon which otherwise it would have been produced; or it may be destroyed by accident, lopped off by design, or strangled by the active vegetation of the stem. These causes operate such a change in the appearance of trees, that one who knew nothing of the more minute character, would hardly believe that a young and vigorous Scotch fir, with its branches perfect to the ground, was the same species with the tall and branchless trunk that stands alone by some ruin, with one or two little bonnets of leaves at the top, not bigger to appearance than rooks' nests. This character is, however, a most important one, both as from it the tree may be known, and as it establishes the fact of a specific character in all parts of the tree, which may be modified, but not obliterated, and which is at once the production and the proof of one mode of vegetation peculiar to the species, and therefore its true and natural character.

This double spiral is produced by the branches, the leaves, and the scales, alternating with each other in their successive whorls; so that the individuals of each whorl fall on the middle of that below. They do that most remarkably in the pines; and that is what might be expected. With the exception, perhaps, of the araucarias, the timber of pines has the straightest vessels, and, in proportion to the *cement of turpentine* in it, is the most easily split; *probably also* the splintery character in the arau-

carias is owing more to the want of turpentine than to any deficiency of lateral cohesion in the vessels. From the straightness of the vessels in the pine, each whorl must occasion a lessening of the vegetative action, immediately over each of its members, which will be the same as an increase in the intervals; and as the new production is the result of that greater action, it must, as a matter of course, take place at those intervals. The turns of the spiral will be more open in proportion as the growth of the tree is more rapid; but we may consider it as a general law, that trees which have straight vessels, and branch in horizontal whorls, must have the members of those whorls alternate; and, further, that if there is a destruction of the lateral buds on any one season, there will be a tendency to more vigorous budding and branching on that side the next season. The spruces have this character less marked in the branches and leaves than the pines, and their cones have not the spirals so perfect: these vessels, also, are less straight, and their timber not so easily cleft as the firs. The larches and cedars, which have the leaves in tufts, and the wood with still more lateral cohesion, have the scales of the cones imbricated, so that the spirals are not easily traced. A much closer imbrication takes place in the cones of the araucarias; and so much does it agree with the character of the leaves, that in the *A. imbricata*—upon the twigs of which the leaves are thickly serried—the scales of young cones very much resemble leaves in appearance. In the remaining divisions of the order, in which the habit of the pine is still more departed from, and there is hardly a trace of branching in whorls, no spiral appears either in the insertions of

still the specimens which are found in various parts of this country show that this, which resembles the deodara more than any other of the family, is by no means a contemptible tree. Whatever the cedar of Lebanon was, it is generally supposed by those who treat of sacred antiquities, that the operations carried on in Lebanon, under Hiram, who did "all his desire concerning timber of cedar, and concerning timber of fir," and who had "four score thousand hewers in the mountains," besides "three score and ten thousand who bear burdens," must have greatly thinned the forest, for materials to construct the temple and the various other buildings which he erected.

As the pines are highly characteristic of those countries in which they are found, their geographical distribution is a matter of some interest. Around the whole northern regions, they are found in the family of the true pines, forming the most extensive forests, and perhaps the most productive in timber that occur any where on the surface of the earth. The cedars are situated on the mountains of more southern latitudes, wholly in the eastern continent—for the species which are called cedars in America are junipers. As we proceed southward we lose the characteristic pines of the northern latitudes, and come to trees of different character. But it is not in the living vegetation alone that we find traces of those trees; at least species having the same habit of growth, and very similar structure of wood, are found in many of the coal formations, and also in the sand-stones, though in the latter only the form of the timber remains, its less durable substance being expelled and replaced by the sand. Thus it appears that in

the regions of the north there has in the former generation existed a vegetation of plants, closely allied to the pine family as they now exist; but also differing from them in many important particulars.

It is, however, in the plants with two cotyledons which are more characteristic than the pine, that we find the most perfect development of vegetable action; and therefore in them we shall take a more extended or rather a more comprehensive view of the action of vegetables than we have done in any of the others.

CHAPTER VI.

STRUCTURE OF PLANTS WITH TWO COTYLEDONS.

ALL plants of this kind are originally produced in the natural order of their succession, though are and even accidental circumstances may produce alterations in them. These seeds are all produced from flowers of some kind or other; and a seed is never perfect unless there is a union of two distinct parts, which union may be considered as constituting the act of vegetation. Those two parts are sometimes situated in the same flower upon one plant, sometimes in different flowers upon one plant; and sometimes in flowers upon different plants. The first are for the sake of distinction called double-sexed, or hermaphrodite flowers, to which there are some resemblances among the invertebrated animals, in which the whole originating of the offspring is confined to one individual;

but still even in these there must be a union, before there can be a succession. The essential part of the flower containing the rudiment of the seed, and fitted for bringing that forward to maturity, so that it may be laid in the earth, something in the same way as the egg of a reptile is laid in the earth, or that of a fish cast upon the waters, in order that the operation of natural causes, external of itself, may quicken it into the new being,—the essential part of this is technically *gynia*, which is a sort of Greek word, signifying that which is capable of being fertilised and rendered productive; and the most simple or general word from which this one is formed, is the Greek name for the earth, as the general source or common mother of all terrestrial fertility. The other part, whether in the same flower or in a different one, is called *ander*, which means the fertiliser, or that which has the power of communicating to the other that stimulus in consequence of which it is enabled to elaborate a seed capable of growing. When those plants are on the same tree, but in different flowers, the tree is said to be *monœcious;* that is, the two parts are in one house, though they are not, so to speak, in one room. If they are on different plants, the plant is called *diœcious*, which means that they occupy two houses, as it were. These names are a little fanciful, but they are, perhaps, not on that account the less adapted for being an artificial memory of the facts, as we have now explained them. In those species which have the parts on distinct plants, the seeds, though both produced on the fertilisable plant, are distinct from the commencement; and those who have much practice in such matters can, by sowing the one or the other,

obtain a specimen of either plant at pleasure. In a state of nature, too, each seed, each flower, and each organ, is understood to be constant to the species, so that when seeds are, as it were, sown by the hand of nature, there is no interference between plant and plant; but those plants which are best adapted to the natural circumstances of the place, continue their succession, though there are many instances in which the general vegetation of a country has changed during the period of recorded history. When, however, man interferes, ignorant as he is of those natural adaptations to which unassisted nature works so very perfectly, he finds that he can blend together those plants which have a great natural or structural resemblance; and it is this which gives the hand of the cultivator so much power over the vegetable kingdom; and which, because vegetation is the ground-work of all growth of life upon the earth, thereby brings the animal kingdom also within the reach of his management. This is a very beautiful adaptation, and one which runs through the whole of creation as a law, far more invariable than any which was ever given forth by the kings of the Medes and Persians, when God saw meet to arm them with the plenitude of their power, as the instruments of his dealing with the nations.

The few particulars which we have now stated with regard to the flowering of plants and the fertilising of their seeds, are not to be considered as peculiar to plants with two cotyledons, but as being common to all flowering plants, whether there are cotyledons or lobes in the seed or not. It is probable also, that where the production of the sporule or germ, by what name soever it may be called, is

internal in the body of the plant, without any development which we can regard as a distinct and visible flower, there is still a union of two parts, or a distinct act of vegetation, before the germ, whatever it is, can be brought into a condition fit for originating a new plant. It is true that where we have no observation we can have no appeal to facts; but still after analogy is well established throughout the whole range of our observation in any one department of nature, (and here so generally established that there is not one known exception to it,) we may venture to use it as our guide in those portions of the same department, which our observation will not reach; for, though we ought never to trust to analogy in any one department where we can make use of observation, yet, when observation fails us, analogy becomes the only instrument on which we can depend for the extension of our knowledge; and it is very frequently the best guide that our observation can have in those departments of knowledge, the truths of which, when once we have learned how to arrive at them, are fairly within the scope of our power of observing.

The flowering of plants and the maturing of their fruit, or rather of their seeds, which are the germs of successional races, are by far the most important parts of their economy; and there is no display of nature which gives so general and so simple pleasure to the human heart as the operation of flowering. The forms, the colours, the odours, and the durations of flowers differ so much from each other, that very much of the systematic arrangement of plants is founded on them; and there is *this remarkable* difference between vegetables and

animals, that while the double-sexed animal is always regarded as holding a low place in the scale of animal life, the double-sexed flower is regarded as holding the very highest place in the scale of vegetable life. When a flower is complete, it may be said to consist of four distinct parts, independently of the twig or stem, or other part of the plant, to which it is attached. Two of those parts, the ones to which we have already alluded, are essential, and the other parts are only accessory, though they are necessary to perform with certainty that function which is the essential business of the flower. The fertilisable part is compound, consisting of an ovarium or seed-vessel, which is variously situated, according to the nature of the plant; and of conducting parts which convey the energy of the fertilising part to the seed. When this has once been done, there is immediately a double action in the seed-vessel, one part of which is to be considered as maternal and the other fœtal, just as is the case in the animal kingdom. All these parts, or rather sections of one part, differ greatly in their forms and in their relative positions in different kind of plants; but though there are very convenient means of distinguishing one plant from another, the grand and essential function is substantially the same in all cases.

The fertilising part is also compound; but it is formed for discharging, whereas the other part is formed for receiving; and the most essential part of it, namely, that which contains the fertilising energy, is at the most distant extremity; and in consequence exposed to the inclemency of the weather, whereas the essential portion of the other part, namely, that which contains the rudiment of

the seed, is more or less protected in every case, and in some cases the protection is very complete. In consequence of this, it is most frequently by the distribution of this fertilising part, occasioned by the inclemency of the weather, or by some other casualty, that the fertility of flowers is prevented, while the seed in its rudimental state, though exposed to attacks from various kinds of insects, is comparatively safe from the weather.

The other parts, which though necessary are not so absolutely essential as those which have now been mentioned, are the envelopes which surround those more essential parts, protect them from injury in their early stages, and no doubt contribute to bring them forward. There are two of them,—an external one, which usually partakes more or less of the general appearance of the common green and temporary structures of the plant. This is the *calyx* or cup, which is variously divided into portions called sepals; and it is sometimes placed above the seed vessel, and sometimes below it: thus in the numerous tribe of the roses, and in very many fruits, the trees that bear many of which are somewhat allied in character to the roses, it is above the seed vessel, and remains upon the envelope of that vessel after it swells into a fruit, as may be seen in pears and various other fruits. In other cases, again, it remains enclosing the basal end of the seed vessel, or the fruit, whatever that may be; and of this we have familiar instances in the potato, the egg plants which belong to the same natural family, and a variety of others. Sometimes this calyx wastes away, or is what is called deciduous; and there are other cases in which it is closely united with the other part; and some

where there is so much of a calyx-like appearance in the whole envelope of the essential parts of the flower, that the other part is generally considered as wanting.

That other part is called the *corolla*, which is nearly the same as to say the "crown" of the flower. This is the portion of the flower in which, generally speaking, the greatest beauty is displayed, and that in fact to which the name flower is more immediately restricted, because the texture of it is more delicate, and the colours brighter, than those of the other parts. It is very variously formed and divided; and the parts of it are technically called *petals*. Generally speaking, these form but a single row, but sometimes they are double, and in other cases they consist of many rows. It is upon this part of the flower that the florist who wishes to procure beautiful varieties of flowers, exerts the greater part of his skill; and it is remarkable to what extent culture can direct the action of a plant toward the production of this part of its flower; for there are many species which, when in a state of nature, have only one row of petals, and are very fertile, are changed by art into flowers containing a vast number of petals, larger in size and finer in their colouring than the natural ones; but which flowers are destitute of fertility, or at all events have it very much diminished.

These changes often give us a good deal of information concerning the nature of flowers and the relation of their parts to each other. When such changes are made in a flower; it is, generally speaking, if not invariably, the anthers, or fertilising parts, on which the change is produced. Hence we may conclude that the corolla is more connected

with the anthers, and the calyx more with the part of the flower which produces the seed. The corolla is never persistent, that is, it never remains until the seed and fruit are matured. It is attendant upon the anthers, and it seems in some way or other to produce a much greater heat than there is in the other parts of the plant; for when the flower has reached its utmost perfecting and expansion, and the anthers are about to burst their little capsules, and discharge their fertilising contents, the temperature of that part of the flower is always warmer than that of the rest of the plant. The pollen or fertilising matter consists of small vesicles, inclosing some sort of air, and, generally speaking, light enough for floating in all directions, provided the atmosphere is sufficiently warm; but how long it retains its virtues we have no means of ascertaining. Bees and other honey-gathering insects are of great service to flowers, by dispersing this pollen, not only over the individual flowers, but over the neighbouring ones; but they exact wages for the work which they thus perform, as they carry off a large portion of the pollen, to be treasured up as food for their progeny. This does not, however, rob the plant; for, if the pollen is in a healthy state, it seems that very little of it suffices for the functions which it has to perform; and it is highly probable that it acts merely as a stimulus, and that no part of it goes in substance to the formation of the seed.

If the season is favourable, and the fertilising of the plant takes proper effect, the anthers and petals very speedily perish, and nearly at the same time; but the petals are thrown off very little decayed. On the other hand, if the weather is unfavourable

and the action of the flower fails in its more essential part, the petals linger in their places, and shrivel and dry up there. It is understood that the same growth of a plant never flowers twice, though there are some cases in which it is not easy to state the fact with precision, because the flowers of plants which have the habit of producing lateral buds, may seem to appear more than once upon the same external part of the bark. Their so appearing is, however, a deception, for no exogenous plant has its last growth upon the bark, in any place except the young twigs, in any wound that may be healed; and, as we find in trees, which are pollarded or headed down, to too small an expansion of leaves for their general action, there is a great tendency to the production of buds and young shoots at the places where they are wounded. Many of the trees, especially those of tropical climates have, however, the vegetable action going on so constantly in them, that they are almost in continual flower; and indeed, there is so much difference in the action of plants in this respect, that it is not possible to bring out their characters with sufficient force in a general sketch. The subject is, however, one of very great interest, and it has the advantage of being also one the prosecution of which is as pleasing as it is instructive.

There is something very interesting in the germination of plants, or the mode in which, according to their general habits, they originally start into growth. The complete development of the young plant always consists of two distinct plants, which are separated by a collet, or coronal plane, which appears to be the separation of two distinct parts, even in those plants which are so miscellaneous in

their growth, that a cutting will grow with either end placed in the earth, and any node or joint, or even sometimes the cambium, or matter which is to form the production of wood and bark for the season, will give out root fibres from its general structure, as is not uncommon in those plants which are so replete with vegetating energy, that they will send out lateral buds indiscriminately at all parts, whether the joints or the spaces intermediately between them. Where this is the case, there seems to be a much less definite distinction between the stem, or upward part of the plant, and the root or downward part, and thus the collet is much less perfect. In such cases, both powers appear to be so far blended, both in the upward part of the plant and in the downward, that portions of the branches are always in a condition, when the proper time is chosen, for forming roots, and the roots for forming stems. There are, however, few cases, and perhaps none, in which those two powers are exactly equal to each other, either in the upper or under part of the plant. The young stem, or sucker, which grows from the roots, has never the same vigour, nor acquires the same size, as the original stem, which is produced directly from the seed at its first germination; and in like manner the cutting never produces a root which can support it for the same length of time as the original root which is produced directly from the seed. Thus, though there is a diffusion of both the energies over both the parts of the plant, there is still a superiority in that part which preserves the situation that it had in the original, or, as it is sometimes called, the virgin tree, as produced from the seed. The same thing happens in the case of trees

which are grafted on roots not their own; for though the graft may be of a character which produces much more wood than the stock on which it is grafted, and this is considered as by far the more judicious mode of grafting, in order to produce healthy and durable trees; yet the production is never so great as if the plant had been allowed to grow on its own root. In one respect, however, it answers the purpose of the cultivator much better; for the flowering and the fruiting of plants are generally in the inverse ratio of their increase in size, that is to say, if they remain healthy; and therefore this grafting, though the tendency of it is to produce trees which are less stately, always produces a greater abundance of flowers or fruit while the tree lasts; and thus the cultivator is enabled to turn the activity of the plant chiefly into that channel which answers his purpose the best.

In the mode in which plants, especially those which are to grow for a number of years, originally start from the seed, there is also something to be learned; for in proportion as the plant is to be of longer duration it starts earlier in the earth; and in proportion as it is shorter-lived it starts earlier in the air. The oak for instance, which is one of the longest-lived of the common forest trees of the British Islands, starts first in the root, and has not only the primary radicle considerably lengthened, but has it furnished with lateral fibres, before the plumula, or part which is to be the future stem, is anything else than a mere rudimental tubercle; plants of weakly structure, or of more brief duration, work upwards at the beginning of their action; and such plants do not suffer so much by

having their original or tap roots broken, as those in which these tap roots are the first parts originally formed.

But the instructive general truths which present themselves upon an examination of the vegetable kingdom in the habits and action of the larger groups, to say nothing of the particular structures, appearances, and uses of individual species, would fill many volumes; and the knowledge of them can be obtained only by an extended course of botanical reading, combined with a careful study of living plants in all situations, and at all seasons, as they may come under the notice of the observer. And it is impossible to say how much the character of man would be improved and his enjoyment of life heightened, if he would so discipline himself, that every ramble o'er the flowery meadow, through the shady forest, or across the wind-beaten hill, should be a lesson of that most delightful of all instruction, which takes the mind captive at its pleasure, and mingles with that gratification of the sense which the growing and flowering world imparts in such copiousness and purity, an uplifting of the fancy, an outgoing of the understanding, which should elevate the mental man, in the fervency of enlightened faith, to the footstool of the Eternal Throne, and make him feel the wisdom, the power, and the goodness of the Almighty, in every creature which he has made, and every law which he has established for its economy.

CHAPTER VII.

GENERAL REFLECTIONS.

PERHAPS we cannot conclude this branch of the subject better than with an essay on the productions, nourishment, and operation of plants and animals.

Creatures produce their own kind. When I survey the works of nature with an attentive eye, I am surprised to find with what marvellous exactness every creature draws its own picture, or propagates its own likeness, though in different manners of operation. The fox produces a living fox; the goose drops her egg, and hatches the young goose; and the tulip lets fall its seed into the earth, which ferments and swells, and labours long in the ground, till at last it brings forth a tulip.

Is it the natural sagacity of foxes that enables them to form their own image so accurately? By no means; for the goose and the flower do the like: the sprightly and the stupid, the sensible and the senseless, work this wonder with equal regularity and perfection; and the plant performs as well as the animal.

'Tis not possible that any of them should effect this by any peculiar rules of art and contrivance: for neither the one nor the other is at all acquainted with the composition or progress of their work. The bird is entirely ignorant of the wondrous vital ferment of her own egg, either in the formation of it, or the incubation: and the mother-plant knows as much of the parts of the young plant, as the mother-animal knows of the inward springs and movements of the young little animal. There could be no contrivance here: for

not any of them had any thought or design of the final production: they were all moved, both the beast, bird and flower, by the material and mechanical springs of their own nature to continue their own species, but without any such intent or purpose.

Give souls to all the animal race, and make those souls as intelligent as you can; attribute to them what good sense you please in other affairs of their puny life; allow the brutes to be as rational and as cunning as you could wish or fancy, and to perform a thousand tricks by their own sagacity; yet in this matter, those intellectual powers must all stand by as useless: the senseless vegetable has as much skill here as the animal; the goose is as wise as the fox or the greyhound; they draw their own portraits with as exquisite art and accuracy, and leave as perfect images behind them to perpetuate their kind. Amazing proof and incontestible argument of some superior wisdom! Some transcendent contriving mind. Some divine artificer that made all these wondrous machines, and set them at work! The animal and the vegetable, in these productions are but mere instruments under his supreme ruling power; like artless pencils in a painter's hand, to form the images that his thought had before designed: and 'tis that God alone, who before all worlds contrived these models of every species in his own original idea, that appoints what under-agents he will employ to copy them.

In the week of the creation, he bade the earth teem with beasts and plants: and the earth like a common mother brought forth the lion, the fox, and the dog, as well as the cedar and the tulip, *Gen. i. 11. 24.* He commanded the water to produce the first fish and fowl; behold the waters

grow pregnant; the trout and the dolphin break forth into life; the goose and the sparrow arise and shake their wings, Gen. i. 20, 21. But two common parents, earth and water to the whole animal and vegetable world! A God needs no more. And though he was pleased to make use of the water and the earth in these first productions, yet the power and the skill were much the same as if he had made them immediately with his own hands.

Ever since that week of creative wonders, God has ordered all these creatures to fill the world with inhabitants of their own kind; and they have obeyed him in a long succession of almost six thousand years. He has granted (shall I say) a divine patent to each Creature for the sole production of its own likeness, with an utter prohibition to all the rest; but still under the everlasting influence of his own supreme agency upon the moving atoms that form these plants or animals. God himself is the creator still.

And 'tis evident that he has kept a reserve of sovereignty to himself, and has displayed the ensigns of it in some important hours. Egypt was once a glorious and tremendous scene of this sovereignty: 'twas there that he ordered the rod of Moses, a dry and lifeless vegetable, to raise a swarm of living animals, to call up a brood of lice in millions without a parent, and to animate the dust of the ground into a noisome army.

It was there he bade Aaron wave the same rod over the streams and the ponds, and the silent rod under divine influence would bring forth croaking legions out of the waters without number.

But these *are his* works of miracle and astonishment, *when he has* a mind to shew himself the

sovereign and the controller of nature: without his immediate commission not one creature can invade the province of another, nor perform any thing of this work but within its own peculiar tribe. Even man the glory of this lower creation and the wisest thing on earth, would in vain attempt to make one of these common vegetables, or these curious animated moving machines. Not all the united powers of human nature, nor a council of the nicest artificers with all their enginery and skill, could form the least part of these works, can compose a fox's tail, a goose quill, or a tulip-leaf. Nature is the art of God, and it must for ever be unrivalled by the sons of men.

Yet *man can produce a man.* Admirable effect but artless cause! A poor limited, inferior agent! The plant and the brute in this manner are his rivals, and his equals too. The human parent and the parent bird form their own images with equal skill, and are confined each to its own work. So the iron seal transfers its own figure to the clay with as much exactness and curiosity as the golden one: both can transfer only their own figure.

This appears to me a glorious instance wherein the wisdom and power of God maintain their own supremacy, and triumph over all the boasted reason and intellectual skill of men; that the wisest son of Adam in this noblest work of nature, can do no more than a flower or a fly; and if he would go out of his own species, and the appointed order of things, he is not able to make a fly, or a flower; no, not a worm, nor a simple bulrush. In those productions wherein mankind are merely the instruments of the God of Nature, their work is *vital and divine*; but if they would set up for prime

artificers, they can do nothing: a dead statue, a painted shadow on a canvas, or perhaps a little brazen clock-work, is the supreme pride of their art, their highest excellence and perfection.

Let the atheist then exert his utmost stretch of understanding: let him try the force of all his mechanical powers to compose the wing of a butterfly, or the meanest feather of a sparrow: let him labour, and sweat, and faint, and acknowledge his own weakness: then let him turn his eye, and look at those wondrous composures, his son, or his little daughter; and when their infant tongues shall inquire of him, and say, "Father, who made us?" let him not dare assume the honour of that work to himself, but teach the young creatures that "there is a God," and fall down on his face, and repent and worship.

It was God who said at first, "Let the earth bring forth grass, and the herb yielding seed—after his kind—and the living creature after his kind;" and when this was done, then with a creating voice he bid those herbs and those living creatures, "be fruitful and multiply" to all future generations. "Great things doth he which we cannot comprehend.—But he sealeth up the hand of every man, that all men may know his divine work." Gen. i. 11, 25; Job. xxxvii. 5, 7.

The Laws of Nature sufficient for the Production of Animals and Vegetables.—Will you suppose that it derogates from the glory of Divine Providence, to represent the great engine of this visible world, as moving onward in its appointed course, without the continual interposure of hi hand? It is granted, indeed, that his hand is ever *active in preserving* all the parts of matter in all

their motions according to these uniform laws: but I think it is rather derogatory to his infinite wisdom, to imagine that He would not make the vegetable and animal, as well as the inanimate, world of such sort of workmanship, as might regularly move onward in this manner for five or six thousand years, without putting a new hand to it ten thousand times every hour—I say, ten thousand times every hour; for there is not an hour nor a moment passes, wherein there are not many millions of plants and animals actually forming in the southern or northern climates.

He that can make a clock, with a great variety of beauties and motions, to go regularly a twelvemonth together, is certainly a skilful artist; but if he must put his own hand to assist those motions every hour, or else the engine will stand still, or the wheels move at random, we conceive a much meaner opinion of his performance and his skill. On the other hand, how glorious and divine an artificer would he be called that should have made two of these pieces of clock-work above five thousand years ago, and contrived such hidden springs and motions within them, that they should have joined together, to perpetuate the species, and thus continue the same sort of clocks in more than a hundred successions down to this day? though each of their springs might fail in forty years' time, and their motions cease, or their materials decay, yet that by the means of these two original engines, there should be engines of the same kind multiplied upon the face of the earth, by the same rules of motion which the artist had established in the day when he first formed them.

Such is the workmanship of God; for nature is *nothing but* his art. Such is the amazing pene-

tration of divine skill, such the long reach of His foresight, who has long ago set his instruments at work, and guarded against all their possible deficiencies; who has provided to replenish the world with plants and animals to the end of time, by the wondrous contrivance of his first creation, and the laws he then ordained.

Thus every whale, eagle, and apple-tree, every lion and rose, fly and worm, in our age, are as really the work of God, as the first which he made of the kind. It is so far from being a derogation to his honour, to perpetuate all the species by such instruments of his agency for many ages, that it rather aggrandizes the character of the Creator, and gives new lustre to Divine Wisdom: for if any thing can be said to be easier or harder in this sort of Almighty work, we may suppose it a more glorious difficulty for a God to employ a sparrow or an oyster to make a sparrow or an oyster, than to make one immediately with his own hand. Perhaps there is not a wasp or a butterfly now in the world, but has gone through almost six thousand ancestors, and yet the work of the last parent is exquisitely perfect in shape, in colour, and in every perfection of beauty, but it is all owing to the First Cause.

This is wisdom becoming a God, and demands an eternal tribute of wonder and worship.

Of the Nourishment and Growth of Plants.—In the beginning of time and nature, at the command of God, the earth brought forth plants and herbs, and four-footed animals in their various kinds; but the birds of the air, as well as the fishes, were produced by the same command out of the waters. This was intimated in a former section. *The water* and the earth were the first

appointed mothers, if I may so express it, of all the animal and vegetable creation. Since that time they cease to be parents indeed, but they are the common nurses of all that breathes, and of all that grows. Nor is the wisdom of God much less conspicuous in constituting two such plain and simple beings as the earth and water, to be the springs of nourishment and growth to such an innumerable variety of creatures, than it was in the formation of them out of two such materials. Is it not counted an admirable piece of divine contrivance and wisdom, that the single principle of gravitation should be employed by the Creator, to answer so many millions of purposes among the heavenly bodies in their regular revolutions, as well as among the inhabitants, and the furniture of this earthly globe where we dwell? And may it not be esteemed as astonishing an effect of the same supreme wisdom, that two such simple things as water and earth should be the common materials out of which all the standing ornaments, the vegetable beauties, and the moving inhabitants of this our world, whether flying or creeping, walking or swimming, should receive their continual sustenance, and their increase?

Let us first consider this as it relates to the vegetable part of the creation. What a profusion of beauty and fragrancy, of shapes and colours, of smells and tastes, is scattered among the herbs and flowers of the ground, among the shrubs, the trees, and the fruits of the field! Colouring in its original glory and perfection triumphs here; red, yellow, green, blue, purple, with vastly more diversities than the rainbow ever knew, or the prism can *represent*, are distributed among the flowers and

blossoms. And what variety of tastes, both original and compounded, of sweet, bitter, sharp, with a thousand nameless flavours, are found among the herbs of the garden! What an amazing difference of shapes and sizes appears amongst the trees of the field and forest in their branches and their leaves! And what a luxurious and elegant distinction in their several fruits! How very numerous are their distinct properties, and their uses in human life! And yet these two common elements, earth and water, are the only materials out of which they are all composed, from the beginning to the end of nature and time!

Let the gardener dress for himself one field of fresh earth, and make it as uniform as he can; then let him plant therein all the varieties of the vegetable world, in their roots or in their seeds, as he shall think most proper; yet out of this common earth, under the droppings of common water from heaven, every one of these plants shall be nourished, and grow up in its proper form; all the infinite diversity of shapes and sizes, colours, tastes, and smells, which constitute and adorn the vegetable world (would the climate permit), might be produced out of the same clods. What rich and surprising wisdom appears in that Almighty Operator, who out of the same matter shall perfume the bosom of the rose, and give the garlick its offensive and nauseous powers! Who from the same spot of ground shall raise the liquorice and the wormwood, and dress the cheek of the tulip in all its glowing beauties! What a surprise, to see the same field furnish the pomegranate, and the orange-tree with the juicy fruit, and the stalks of corn with their dry and husky grains! to observe

the oak raised from a little acorn, into its stately growth and solid timber, out of the same bed of earth that sent up the vine with such soft and feeble limbs! What a natural kind of prodigy is it, that chilling and burning vegetables should arise out of the same spot! that the fever and the frenzy should start up from the same bed, where the palsy and the lethargy lie dormant in their seeds! Is it not exceedingly strange, that healthful and poisonous juices should rise up in their proper plants out of the same common glebe, and that life and death should grow and thrive within an inch of each other?

What wondrous and inimitable skill must be attributed to that Supreme Power, that First Cause, who can so infinitely diversify effects, where the servile second cause is always the same!

It is not for me in this place to enter into a long detail of philosophy, and shew how the minute fibres and tubes of the different seeds and roots of vegetables take hold of, attract, and receive, the little particles of earth and water proper for their own growth; how they form them at first into their own shapes, and send them up aspiring above ground by degrees, and mould them so as to frame the stalks, the branches, the leaves and the buds of every flower, herb, and tree. But I presume the world is too weary of substantial forms, and plastic powers, to be persuaded that these mere creatures of fancy should be the operators in this wondrous work. It is much more honourable to attribute all to the design and forethought of God, who formed the first vegetables in such a manner, and appointed their little parts to ferment under the warm sunbeams, according to such established laws of

motion, as to mould the atoms of earth and water which were near them into their own figure, to make them grow up into trunk and branches, which every night should harden into firmness and stability; and again, to mould new atoms of the same element into leaves and bloom, fruit and seed, which last being dropped into the earth should produce new plants of the same likeness to the end of the world.

It is easier for the sons of men to stand and wonder, and adore God the Creator, than to imitate, or even to describe, his admirable works. In the best of their descriptions and their imitations of this divine artifice, they do but chatter like Hottentots, and paint like Goths and Vandals.

Of the Nourishment and Growth of Animals.— Let us proceed in the next place to survey new wonders. All the animals of the creation, as well as the plants, have their original nourishment from these simple materials, earth and water. For all the animal beings which do not live upon other animals, or the produce of them, take some of the vegetables for their food; and thus the brutes of prey are originally indebted to the plants and herbs, i. e. to the earth for their support, and their drink is the watery element. That all flesh is grass, is true, in the literal, as well as the metaphorical sense. Does the lion eat the flesh of the lamb? Doth the lamb suck the milk of the ewe? But the ewe is nourished by the grass of the field. Does the kite devour the chicken, and the chicken the little caterpillars or insects of the spring? But these insects are ever feeding on the tender plants, and the green products of the ground. The earth *moistened with* water is the common nurse of all.

Even the fishes of the sea are nourished vegetables that spring up there, or by preyin lesser fishes which feed on these vegetables.

But let us give our meditations a loose on entertaining subject, and we shall find num instances of wonder in this scene of divine trivance.

1. What very different animals are nouri by the same vegetable food! The self-same bage or fruits of the earth, by the divine law nature and providence, are converted into anim bodies of very different kinds. Could you ima that half the fowls of the air, as different as are from the crow to the tit-mouse, should d their flesh and blood from the productions o same tree, where the swine watches under boughs of it, and is nourished by the fruit? need I stay to take notice what numerous in find their nests and their food all the sun season from the same apples or apricots, p or cherries, which feed hogs and crows, a hundred small birds. Would you think tha black and the brindled kine, with the horses grey and bay, should clothe themselves with hairy skins of so various colours, out of the green pasture where the sheep feeds, and c himself with his white and woolly fleece? A the same time the goose is cropping part o grass to nourish its own flesh, and to array with down and feathers! Strange and stupen texture of the bodies of these creatures, that sh convert the common green herbage of the into their different natures, and their more diff clothing! But this leads me to another rema

2. *What* exceeding great diversity is fou

the several parts, limbs, and coverings even of the same creature? An animated body is made up of flesh and blood, bones and membranes, long hollow tubes, with a variety of liquors contained in them, together with many strings and tendons, and a thousand other things which escape the naked sight, and for which anatomy has hardly found a name: yet the very same food is by the wondrous skill and appointment of the God of nature formed into all these amazing differences. Let us take an ox to pieces, and survey the wondrous composition. Besides the flesh of this huge living structure, and the bones on which it is built, what variety of tender coats and humours belong to that admirable organ the eye! How solid and hard are the teeth which grind the food! How firm the general ligaments that tie the joints of that creature together! What horny hoofs are his support, and with what different sort of horny weapons has nature furnished his forehead! Yet they are all framed of the same grassy materials: the calf grazes upon the verdant pasture, and all its limbs and powers grow up out of the food to the size and firmness of an ox. Can it be supposed, that all these corpuscles, of which the several inward and outward parts of the brute are composed, are actually found in their different and proper forms in the vegetable food? Does every spire of grass actually contain the specific parts of the horn and the hoof, the teeth and the tendons, the glands and membranes, the humours and coats of the eye, the liquids and solids, with all their innumerable varieties in their proper distinct forms? This is a most unreasonable supposition. No, it is the *wisdom of the* God of nature that distributes this

uniform food in the several parts of the animal by his appointed laws, and gives proper nourishment to each of them.

Again, 3. If the food of which one single animal partakes be ever so various and different, yet the same laws of motion, which God has ordained in the animal world, convert them all to the same purposes of nourishment for that creature. Behold the little bee gathering its honey from a thousand flowers, and laying up the precious store for its winter food! Mark how the crow preys upon a carcass: anon it crops a cherry from the tree, and both are changed into the flesh and feathers of a crow. Observe the kine in the meadows, feeding on an hundred varieties of herbs and flowers; yet all the different parts of their bodies are nourished thereby in a proper manner: every flower in the field is made use of to increase the flesh of the heifer, and to make food for men: and out of all these varieties there is a noble milky juice flowing to the udder, which provides nourishment for young children.

So near akin is man, the lord of the creation, in respect of his body, to the brutes that are his slaves, that the very same food will compose the flesh of both, and make them grow up to their appointed stature. This is evident beyond doubt in daily experiments. The same bread-corn which we eat at our tables will give rich support to sparrows and pigeons, to the turkey, and the duck, and all the fowls of the yard: the mouse steals it and feeds on it in his dark retirements; while the hog in the sty and the horse in the stall, would be glad to partake of it. When the poor cottager has nursed up a couple of geese, the fox seizes one of *them for the* support of her cubs, and perhaps the

table of the landlord is furnished with the other to regale his friends. Nor is it an uncommon thing to see the favourite lap dog feed out of the same bowl of milk, which is prepared for the heir of a wealthy family, but which nature had originally designed to nourish a calf. The same milky material will feed calves, lap dogs, and human bodies.

How various are our dishes at an entertainment! How has luxury even tired itself in the invention of meats and drinks in an excessive and endless variety! Yet when they pass into the common boiler of the stomach, and are carried thence through the intestines, there is a white juice strained out of the strange mixture called chyle, which from the lacteal vessels is conveyed into the blood, and by the laws of nature is converted into the same crimson liquor. This being distributed through all the body by the arteries, is farther strained again through proper vessels, and becomes the spring of nourishment to every different part of the animal. Thus, the God of nature has ordained, that how diverse soever our meats are, they shall first be reduced to an uniform milky liquid, that by new contrivances, and Divine art, it may be again diversified into flesh and bones, nerves and membranes.

How conspicuous, and yet how admirable, are the operations of Divine Wisdom in this single instance of nourishment! But it is no wonder that a God, who could create such astonishing and exquisite pieces of machinery as plants and animals, could prescribe such laws to matter and motion, as to nourish and preserve the individuals, as well as to propagate the species, through all ages to the end *of time.*

The Similar Operations of Plants and Animals.—It is with admiration and pleasure we take notice of the regulations of animals even in their earliest hours of life, before they can possibly be taught any thing by remark or imagination. Observe the young sparrows in the nest: see how the little naked creatures open their mouths wide to their dam, as though they were sensible of their dependence on her care for food and nourishment. But the chicken just released from the prison of the shell, can pick up its food with its own bill, and therefore it doth not open its mouth to beg food of the hen that hatched it. Yet the chicken seems to show its dependence too; for when the first danger appears, you see it run and fly to the wing of its dam for protection; as though it knew, that though it could feed itself, yet was it not able to defend itself, but must trust to better security and a parent's wing.

We admire these little creatures, and their remarkable sagacity; we are surprised to find that they distinguish so happily, and pursue their proper interest; that they are so soon acquainted with their abilities and their wants, and come to use their understanding so very early; for it is evident, that the mere faculty of sense, that is, the passive reception of images or ideas, can never be sufficient to account for these wondrous imitations of reason; sense has nothing to do but with the present impression, and includes no reflection or prospect of the past or the future, no contrivance of means to an end, nor any action to obtain it.

But what shall we say, or how shall we account for it, if we are told there are instances almost as admirable as these to be found in the vegetable

world, where we never suspect sense or reason? The vine, as though it were sensible of its own weakness, thrusts forth its long tendrils, which curl round the branches of any stronger tree that stands near, and thus it hangs its weighty clusters upon the arms of the elm that support it. Nay, every cluster has a tendril belonging to it, and if any stronger twig of its own be within its reach, it hangs itself there by this tendril for support. The hop and the lupine, or French bean, as though they knew that they could not stand by themselves, find another way to raise their heads on high; they twine the whole length of their bodies round the poles of the rods which are planted near them; and thus their growth and their fruit are upheld from rotting upon the ground. The ivy, for the same reason, but by another contrivance, climbs up the oak, and sticks close to its sides; and the feeble plant which we vulgarly call the creeper, that can hardly raise itself three feet high alone, thrusts out its claws at proper distances, fixes them fast in the neighbouring wall or building, and mounts by this means to the tops of the highest houses. What variety of artifice is found here among these feeble vegetables to support themselves.

Yet we believe these plants have no understanding, and mankind are all agreed they have no such thing as sense belonging to them; and we immediately recur to the wisdom of God the Creator, and ascribe the contrivance and the honour of it to Him alone. It was He (we say) who gave the vine its curling tendrils, and the creeper its hooky claws; it was He instructed the one to bind

itself with natural winding cords to the boughs of a stronger tree, and He taught the other, as it were, to nail itself against the wall. It was He showed the ivy to ascend straight up the oak; and the hop and the lupine, in long spiral lines, to twine round their proper supporters.

Let us inquire now, What do we mean by such expressions as these? Truly, nothing but this; that God formed the natures of these vegetables in such a manner, as that by certain and appointed rules of mechanical motion they should grow up and move their bodies and their branches so as to raise and uphold themselves and their fruit. Thus, the wisdom of God, the great Artificer, is glorified in the vegetable world.

And why should we not give God the Creator the same honour of his wisdom in the animal world also? Why may we not suppose that He has formed the bodies of brute creatures, and all their inward springs of motion, with such exquisite art, as even in their youngest hours, without reasoning and without imitation, to pursue those methods as regularly, which are necessary for their life and their defence, by the same laws of motion and the same unthinking powers? This is nature, when God has appointed it. This seems to be the true idea, and the clearest explication of that obscure word, "instinct."

If we allow these young animals to perform all their affairs by their own contrivance and sagacity, why do we not ascribe the same sagacity and artifice to vines and ivy, that we do to young sparrows or chickens? The motions of the plants are slower indeed, but as regular and rational as those

of the animals; they show as much design and contrivance, and are as necessary and proper to attain their end.

Besides, if we imagine these little young birds to practise their different forms of motion for their nourishment or defence by any springs of reason, meaning, or design in themselves, do we not ascribe understanding to them a little too soon, and confess their knowledge is much superior to our own, and their reason of more early growth? Do we not make men, or rather angels of them, instead of brute creatures? But if we suppose them to be actuated by the peculiar laws of animal motion, which God the Creator, by a long foresight, has established amongst his works, we give him the honour of that early and superior reason, and we adore the Divine Artificer. Psalm cxlv. 10. "All thy works shall praise thee, O Lord."

But we are lost among these wonders of thy wisdom! We are ignorant of thy divine and inimitable contrivances! What shall we say to Thee, thou All-wise, Creating Power! Thy works surprise us; the plants and the brutes puzzle and confound our reasonings; we gaze at thy workmanship with sacred amazement; thy ways in the kingdom of nature are untraceable, and thy wonders past finding out.

"But what!" will some readers say when they peruse these discourses, "are plants and brutes so very near akin to each other, creatures which we have always distinguished into the sensible and the senseless? Have birds and beasts no more perception or feeling, knowledge or consciousness, understanding or will, than the herbs, the trees, and the *flowers? Is the* grass of the field as wise a thing

as the animal which eats it?" Excuse me here, my friends; I dare assert no such paradoxes. What, if some of the early actions of brute creatures are merely the effects of such machinery and instinct as I before described? It does not follow thence that all the actions and operations of their lives must be ascribed to such a mechanical principle. Even in human nature, where there is an undoubted principle of sense and reasoning, there are some early actions which seem to be the proper effects of such instinct, or mechanism, and are owing to the wondrous divine artifice in the contrivance of their animal bodies, and not to any exercise of their own reasoning powers. How doth the infant hunt after the breast, and take it into its mouth, moving the lips, tongue, and palate in the most proper forms for sucking in the milk to nourish it! How does it readily shut the eyes, to cover them from any danger near! How does it raise its cries and wailings aloud for help when it is hurt! These are certainly the effects of instinct in their outward members, as much as the circulation of their blood, and digestion of their food in their bowels and inward parts.

It is certain, there are several operations in the lives of brute creatures, which seem to be more perfect imitations of reason, and bid fairer for the real effect of a reasoning principle within them, than these early actions which I have mentioned. What strange subtlety and contrivance seem to be found in the actions of dogs and foxes! What artifices appear to be used both by birds and beasts of prey, in order to seize the animals which were appointed for their food, as well as in the weaker creatures, to avoid and escape the devourer! How

few are there of the passions, as well as the appetites of human nature, which are not found among several of the brute creatures! What resentment and rage do they discover! What jealousy and fear, what hope and desire, what wondrous instances of love and joy, of gratitude and revenge! What amazing appearances of this nature are observed in birds and beasts of the more docile and domestic kind! Such as puzzle the wisest of philosophers to give a plain, fair, and satisfactory account how all these things can be performed by mechanism, or the mere laws of matter and motion! But how many actions soever may be performed by brute creatures, without any principle of sense or consciousness, reason or reflection, yet these things can never be applied to human nature. It can never be said, that man may be an engine too, that man may be only a finer sort of machine, without a rational and immortal spirit. And the reason is this—Each of us feels, and is conscious within himself that we think, that we reflect, that we contrive and design, that we judge and choose with freedom, and determine our own actions: we can have no stronger principle of assent to any than present, immediate, intellectual consciousness. If I am assured of the truth of any inference whatsoever, it is because I am sure of my consciousness of the premises, and of my consciousness that I derive this inference from them. My consciousness of these premises therefore is, a prior ground of assurance, and the foundation of all my certainty of the inferences. Let a thousand reasons, therefore, be laid before me, to prove that I am nothing but an engine, my own inward present consciousness of this proposition, *that I have* thoughts, that I have reasoning

powers, and that I have a will and free choice, is a full evidence to me, that these are false reasonings, and deceitful arguments; I know, and am assured, by what I feel every moment, that I have a spirit within me capable of knowing God, and of honouring or dishonouring my Maker, of choosing good or evil, of practising vice or virtue, and that I hereby am bound to approve myself to the Almighty Being that made and governs me, who will reward me in some future state or other, according to my behaviour in this.

And as I can certainly determine this truth, with regard to my own nature, so when I see creatures round about me of the very same species with myself, I justly infer the same truth concerning them also: I conclude with assurance, that they are not mere engines, but have such reasonable and immortal spirits in them, as I find in myself. It is this inference of similar and equal causes from similar and equal effects that makes a great part of the science of mankind.

Besides, I daily hear men discoursing with me on any subject, and giving as regular and reasonable answers to my inquiries, as I do to theirs; I feel within myself, it is impossible for me to do this without thinking, without the careful exercise of my intellectual and reasoning faculties, superior to all the powers of mechanism; and thence I infer, it is as impossible for them to practise the same discourse or conversation, without the powers of a rational and intelligent spirit, which in its own nature is neither material nor mortal.

Let the question therefore which relates to brute *creatures* be determined to any side, it does not at *all affect the* nature, the reason, or the religion of

mankind. It is beyond all doubt, that man is a creature which has an intelligent mind to govern the machine of his body; that man has knowledge, and judgment, and free choice; and unless he approve his conduct to the eyes of his Creator and his Judge, in this state of mortality and trial, he exposes himself to the just vengeance of God in his future and immortal state.

It is certain, that the All-wise and All-righteous Governor of intelligent creatures will not appoint the very same fate and period to the pious and the profane; neither his wisdom, his equity, nor his goodness, will suffer him to deal out the same blessings and the same events in every state of existence, to those who have loved him with all their souls, and those who have hated and blasphemed his name. It is the glory and the interest of the Supreme Ruler of the universe, to make a conspicuous and awful distinction in one world or another, between those who have endeavoured to serve him, and to render his majesty honourable among men, and those who have impiously abused all his favours, ridiculed his thunder, and robbed him of his choicest honours. But if philosophy should fail us here, if it were possible for creatures of such different characters to have nothing in their own natures which was immortal, yet it is a very reasonable thing, that the great Judge of all should prolong their beings beyond this mortal state, that the sons of vice might not go triumphant off the stage of existence, and that the men of virtue might not be always oppressed, nor come to a period of their being, without some testimony of the approbation of the *God that made* them.

CHAPTER VIII.

THE MINERAL KINGDOM—GENERAL VIEW.

THE department of nature upon which we are now about to offer a few brief and general remarks, more with a view to stimulating the desire of knowledge on the part of the reader, than to the gratification of that desire, takes a far wider range than either of those which have already come under our observation. Matter, in the general sense, and without any regard to life or even to growth, is the subject or substance of the mineral kingdom; and in this sense, that kingdom extends not to our earth only, but to the whole material creation, including the remotest stars which the most powerful telescope can find, or the most lively imagination can fancy to be leading its system of worlds in their glorious march through the regions of that space to which no imagination of man can set bounds; and which, in this view of it, brings us more nearly to a just conception of that infinitude of attributes which belongs in its perfection to the creating and directing God, than the contemplation of any individual portion of his working, be that portion whatever it may. When we speak of matter in this general sense, we speak of that of which, viewed abstractedly or apart from some specific form of matter which can come under the cognizance of our senses—we in reality speak of that of which we do know and can know nothing. *From the* changes and modifications that we see *produced* upon every kind of matter both in natu-

ral operations, and in the experiments and ordinary workings of human beings, we find that there is hardly one of those modified forms under which matter appears, which may not be so altered as that the substance shall pass from under the cognizance of our senses, and be to us as if it ceased to exist.

This, however, only teaches us the limited nature of our own powers, and should caution us neither to deny nor to assert beyond the bounds of direct and personal knowledge. The very escaping of substances, which in one form are solid and palpable to the sense, beyond all our means of perception, is sufficient to convince us that not one of those modifications of matter with which we are conversant upon the earth, is absolutely necessary or essential to matter taken in its general sense as the grand element or essence of all that part of creation which is not spiritual; and therefore we do not know how many ruins of old worlds, mightier in their volumes and more abundantly tenanted than our own, or how many elements of new worlds which may roll onward for their appointed periods after ours has passed away from the list of visible things, may be scattered over the regions of space, in portions so minute and so wide apart from each other, that the most subtle of those agencies which regulate the visible creation may not tell upon them to an extent sensible to all the aids of the organs of sense which science has given to the human race. Nor, when we observe what is done, and remember in whose hand the whole of creation is, can we refrain from feeling that if He so willed, the whole of that creation, which is now so beautiful in *the earth* and so glorious in the heavens, *might vanish to our* perception, like the morning

cloud, the early dew, or the unsubstantial phantom of a dream, leaving not a trace behind, so that no mortal men could say that there had been one material existence, or even one extension of space—of which we derive our notions of material existences.

But though, in as far as our limited understandings and imaginations are concerned, the whole might be lost to us, in the same manner and for the same reason as so much of what is and goes on is beyond the limits of our observation, yet we must not measure the Almighty by our finite standard, and suppose that though the fair creation should be withdrawn from our eyes, it could be withdrawn from His kingdom, or that one atom of it could escape from under his constant knowledge, and his constant ruling providence. So that if the decree upon one or upon all the systems of worlds which he has made, and of which decree we see an indication in every natural change that takes place—if this decree should go forth, "Turn ye into nothing;" still, the hand of Providence is over oblivion itself as over a replenished universe, and not the twinkling of an eye could take place before a renovated creation obeyed the counter decree, "Return, ye children of nature," and bloomed in all its beauty.

In consequence of this state of ignorance in which we are, and must ever remain, with regard to the general and abstract nature of that which we call matter, it is necessary for us to be somewhat on our guard when we venture to express opinions concerning it. Though matter in many of its modifications, whether as merely mineral, or as *forming* the substance of plants or animals, is per*ceptible by* our senses, and we can discriminate

between one portion and another; yet it behoves us always to bear in mind that those modifications, or qualities, which bring it within the cognizance of our senses, belong to the individual portion of which we are sensible, and not to matter in the more general sense of the term. Therefore we may say with truth, that matter, in the general sense, is no more an object of direct knowledge by us, than mind is. Consequently, as each depends on its manifestations, the evidence of the existence of both is of the same kind, and those attempts which have been made to deny the existence of the one or the other, because we perceive nothing but the manifestation, are equally futile.

But, subtle and illusive of our senses as matter in the abstract is, we find that, even down to that of which our senses and our instruments can take the most imperfect observation, there is one principle which is common to all matter; and which shows that there is, even in that state of a created thing which is the most remote from life and organization, something more than the mere existing substance. All matter gravitates; that is, every piece and every particle has a tendency to move toward every other, and would move towards it if not restrained by some opposed resistance. The law of this gravitation is quite uniform in its action, and not in the least affected by those qualities of matter which are the result of other modifications. It is in fact the very test of matter, and that which distinguishes it from spirit. We may take a piece of matter and change its form or its state,—it may be of any shape, or it may be solid or liquid, or converted into a gas, and so light as to escape to a more elevated region of

the atmosphere, so as to get beyond the limits of our observation; but amid all those changes there is not the least variation in the gravitating power of the portion of matter. If we remove those external circumstances which act differently upon it according to its form and state, we find that its obedience to the general law of gravitation is the same. Thus, gold is a very heavy and compact substance, and there is only one—platinum, a metal as well as itself, which is weightier in an equal volume or bulk. The down of a feather, on the other hand, is, both on account of its lightness and of its form, capable of floating in the air, and is the part made for the express purpose of enabling a bird to float in that element; but if both are allowed to fall through the height of a vessel from which air is excluded, and thus both are equally at liberty to obey the force or law of gravitation, the one yields just as ready obedience as the other; and the two fall side by side.

There is another general truth resulting from our ignorance of the abstract nature of matter, which is necessary in order to prevent us from falling into error, and that is the impossibility of our knowing whether there is any such thing as a portion of simple matter—that is, of matter which could not be resolved or analysed into parts, having properties different from each other, and also from the compound. There are, indeed, some substances, or specific forms of matter, which no human skill has hitherto been able to resolve into separate elements; but then, since the instruments of chemical analysis were so much improved, and the management of them was so much better understood, as it has been by the chemists of modern times, so

very many substances, once supposed to be perfectly simple, have been resolved into parts differing very much from each other, that it is impossible for us to assign a limit beyond which the species of analysis cannot be carried. It should seem, therefore, that matter in every state in which it is supposed to exist, or even can be imagined to exist, always possesses more than the single property of gravitation; and that what we consider as the very simplest thing in the whole mineral kingdom, is under the agency or power of opposing forces, the balance between which maintains its state.

In speaking of those antagonist forces, under the power of which every portion of matter, however great, and every particle of matter, however small, must be supposed to be maintained in its state, before we can have anything like a rational understanding of the very first step of knowledge of the mineral kingdom, and of which, in the very simplest case which we can suppose, that of two forces, the one may be always said to be the force of gravitation,—in speaking of these forces, we must not view them or describe them as substantive existences, any more than we so look upon and describe what we call the principle of life in plants or in animals. The plant and the animal, which are the same in respect of the life and growth, and without reference to that higher modification of the life which we call sensation in the animal, are higher and more complicated steps in nature's workings; but, in the original principle, they differ not from the rudiment of even the best organised and developed animal. There is a union; and as there is, so there *must be* a power of union. Gravitation is the *simple power of* union, which brings, or tends to

bring, together portions of matter, whether large or small, that are exactly alike; and if they are alike in the balance of gravitation, then each performs exactly an equal part of the union, as obedient to the uniting law. If, on the other hand, they are not alike as weighed in the balance of gravitation, they unite differently; and the one which is the most under a power, whatever it may be, antagonist to the law of gravitation, is the one in which the fact of uniting, if it be an observable one, is the least conspicuous. There are so many modifications of this in all the three kingdoms of material nature, that it is impossible for us to select any one which will represent them all, and yet it is necessary that we should have a clear view of the law in its greatest simplicity.

Now, looking at the law of gravitation only, which simply means that every piece of matter has a tendency to draw to it every other piece, in the ratio of its quantity of matter, and the ratio of the square of its distance; that the effect of distance should vary, as the square of the distance, and vary inversely as that square—that is, become less in proportion as the square becomes greater—is very nearly self-evident. Each body presents toward the other a surface, and the gravitating or attracting energy must be in proportion to that surface. But the measures of surfaces are square measures, of the same shape as the square inches and square feet, of which we speak in common language. Every measurable surface, as affected by or seen from another at a distance from it, becomes apparently less in proportion to the square of the distance to *which it is* removed. Thus, if a piece of board, *containing* one square foot, is placed at the distance

of a foot from the eye; and another board, containing four square feet, that is, a square board having each of its sides two feet long, is placed at the distance of two feet; then, if we have no other means of judgment than that of the sight, both boards will appear to be exactly of the same size; and if they are both placed in exactly the same position from the eye in every respect, the one-foot one will just hide the four-foot one, and no more.

There are many very simple ways of seeing the truth of this without any reasoning: for instance, if a square hole is made in a board set up against the light, and a square board having its side half that of the hole is placed on a stand, so that the middle of the hole and the eye are in the same straight line, it will be found that when the board on the stand is brought exactly midway between the hole and the eye, it exactly covers the hole, if nearer the eye it more than covers it; and if nearer to the hole it does not cover it entirely; and if it is carried to the same distance as this hole, it will cover the half of it. This may be varied with surfaces of any shape, so that they are both of the same shape, and their sides estimated in measures of length are in any proportion; for it will be found that when each is placed at the distance of its side, their effects upon the eye will be the same; and as all surfaces which are of the same shape, or, as it is called similar, are in the proportion of the squares of their corresponding sides, it follows that their effects are inversely as the squares of their distances.

The boards or other surfaces in these cases are seen in *consequence* of the light which comes from

them to the eye; and the difference of effect at a different distance has nothing to do with the kind of surface, so that both are of the same kind, or with the kind of emanation, or action, or power producing an effect, so that it is of the same kind in them both. This varying of every influence which one piece of matter has upon another inversely as the squares of different distances at which the piece of matter exerting the influence may be situated, is, therefore, perfectly general, applying to every case in which the emanation is a mere action or energy, and not a portion of matter.

This enables us to draw a very important distinction in the mineral kingdom, taken generally as including all matter not under the immediate influence of animal or vegetable life. The energy varies inversely as the square of the distance, without the slightest alteration at the piece of matter or body from which it emanates. If, on the other hand, the emanation of substantive matter, the change is in the body from which the emanating matter is separated; and that change is the same to whatever distance the matter which goes off may happen to be carried.

Hence, every energy, or emanation, by what name soever it may be called, and what effect soever it may produce, which, proceeding from any body or piece of matter, remains unvaried in itself, but whose effect varies as the squares of the distances, is not substantive matter, by the giving out of which the body can be at all changed, it is merely action under some of its varied forms and modifications; and, on the other hand, if there is *an emanation* which does not vary in its intensity

inversely as the squares of the distances, that emanation is a real transfer of substantive matter from the one body to the other.

But gravitation or weight is both the only test which we have of the presence or existence of substantive matter, and the only measure which we have of its quantity; and if a portion of matter remains the same as weighed in the scale of gravitation, we conclude with certainty that its quantity, merely as matter, is not in the slightest degree altered, though its state or form should undergo every change which fancy can suppose.

Thus we see that in the very simplest view which it is possible for us to take of matter as forming part of a working creation, it is compound; there is the absolute gravitation, which is measured by and inseparable from the quantity of matter in the body; and the effect of this gravitation as caused by distance, which follows a very different law from the other. Therefore in the very simplest view which we can take of matter generally, there is really a compound action, or power of action, whether it be visible or not; and thus we find in the very constitution of matter itself, even supposing it all of the same kind, an evidence of the same double creation which is so much more conspicuous in the growing and living world,—a creation of matter which is substantive, and a creation of action, or power capable of producing action, which is not substantive, the one as the materials and the other as the workmen; and it is just as impossible to believe that the materials could create the workman, as it is that the workman could create the materials.

This general, or, in so far as observation can go,

this universal, attraction of gravitation is the grand power or principle by which all the matter in the universe, without any distinction of kind or of change, is held together. It is "the golden chain" which binds the heavens and the earth together; and it is also the cause of the permanent general forms of the various great masses by what name soever they may be called, and the means of stability to every more minute thing upon their surface. Still if this principle acted alone, and without an antagonist to press down the other end of the balance to a state of equilibrium, there could be no beautiful system in the universe, and no living or growing thing upon the earth; for in what manner soever matter were at any time distributed, if there were nothing but gravitation, that gravitation would in the course of time bring it into one mass, cold, motionless, and dead. But He who hath fenced in the wide swelling ocean as it were with "gates and bars," hath also ordained general antagonist forces, or powers, or principles, or energies—for as we can see them only in their effects, we cannot tell by what name they ought properly to be called, speaking after the manner of things which are cognizable by our senses.

We shall have occasion, in another chapter, very briefly to notice some of those powers, and the more remarkable effects they produce, so that in the mean time we need only mention that the most general antagonist or opponent of gravitation, by means of which the material universe is held perpetually so nicely poised in the balance as that a single grain would turn it, is that which we call *heat; and* the tendency of this heat, like that of *gravitation,* is to produce motion—and motion in a

direction opposite to that which gravitation tends to produce. We call gravitation an attraction, that is, a drawing towards; and in like manner we may call heat a repulsion, or a driving back; and it is because every portion of matter is drawn the one way and driven the other with equal energy, that it remains perfectly stable. This stability would be, however, the stability of inaction and death; and therefore it is not the kind of stability which the bountiful Creator has given to his splendid work. Whether the centre upon which this balance turns, and which all the powers wherewith created matter is endowed cannot move a single hair's breadth, is the immediate finger of the Eternal himself, or whether it is some second and created cause, some mighty and mysterious energy far above the reach of human philosophy, is not given for man to discover; but still such it is, and so stable is it that while the career of systems, the rotation of planets, the winds of atmospheres, the waves of oceans, the growth of plants, the living functions and the motions of animals, are all carried on—and carried on with such apparent ease, that the resistance against which they act is not felt—the whole is so stable, that not a single atom can be deranged, or break away from that law which has been given to it.

And here there arises a consideration before which the most determined mind may quake as a feeble thing:—Death stands as the witness of life and immortality, and proclaims in words louder than thunder and clearer than lightning, that as without God there could have been no original beginning, so without Him there can be no final *end. The balance* may, as we have said, vibrate,

and that differently both in extent and in time, so as to admit of all those actions or changes which make the one creation ever new, and present us with a fresh world every moment of our lives. But let it vibrate to what extent it may, it always returns after the lapse of some time or other. It is a moment with the trembling leaf; it is three score and ten years with man; it is several hundred years with some of the more goodly trees of the forest; it may be thousands of ages with continents and islands; and no tongue of man can tell after how many revolutions round the sun our earth shall pass away like a shadow; but we may rest assured, that the law which God has given is universal as well as immutable, that at some time or other the balance of those primary forces will be brought to its even poise, and every material thing will pass through that state of which we are endeavouring to give a faint representation—matter acted upon by two antagonists forces exactly equal to each other; and therefore matter dead—dead, but not annihilated. The death is the perfect poise of the balance; annihilation, or returning into nothing, is the withdrawal of that mysterious centre on which the balance turns; and, as we have said, we can refer this to no cause but to God alone. In His hand is this, the grand primal rein of nature's government; and therefore to Him be the glory.

In the preceding remarks, we have used the similitude of the balance and the supporting centre upon which this balance turns, not of course with the slightest allusion to the fact of there being any thing having even the slightest resemblance, in the matter to any material balance, such as those

with which we are familiar in the common business of weighing. We have been speaking of action, not of substance, and therefore, though we have used the term balance to bring what we wished to explain more forcibly and familiarly before the reader, the proper expression would have been the verb "balancing," as the abstract expression for the performance of the action, without allusion to the agent on the subject acted upon. We trust, however, that with this explanation what we have stated cannot be mistaken; and we shall, therefore, proceed to the second step, in the consideration of matter viewed as mineral in the most extended sense—that is, matter which is not organised, or has not been organised, by vegetable or by animal action; or which, if it has once been so organised, has performed its duty in the organic state, and returned to the general inorganic mass.

This second step is the formation of the simplest substance, or class of substances, with which we are acquainted; though here it is necessary to bear in mind, that we know not how compounded or complicated even the most simple mineral substance may be, neither have we any knowledge of those particular powers by which different substances are formed, more than we have of the general powers to which we have already alluded. We see the effect or the result, but of the power or cause we can know nothing. And we may remark in passing, that this is one of the points at which philosophy stands in jeopardy, and from which much error has frequently been produced. We see the succession of events, or the successive states of a substance which undergoes change; and as the first of two *immediately consecutive* states is the antecedent and the

second the consequent, in the order of time, or of succession, we are apt to confound "antecedent" with "cause," and "consequent" with "effect;" and thus to give to two phenomena which are equally results, or productions, the relation of producer and produced, which is the real meaning of cause and effect. This is done in almost every work which treats of the exceedingly subtle and difficult portions of the philosophy of nature, and the necessary result of it is to cast a doubt upon the existence of that God, whose power, wisdom, and goodness are so clearly set forth in all the works of creation, in all their phenomena or appearances, and in all the powers, agencies, or causes, by which those phenomena are produced. It is true that we cannot give the cause—the *vinculum*, or tie, which binds the one event to the other—a name; cannot call it by a noun, as we call a substance, for as we have said, the proper expression for it is verbal, and, being such, it is a subject for the mind only, and not for the senses. If, however, we deny its existence, or even if we do not make ourselves thoroughly acquainted with it, the error or the neglect necessarily goes on to the other two steps of our general understanding and belief:—when we turn our attention to man generally, or inward upon ourselves, we question, or doubt the existence of the cause of man's knowing and acting differently from every other creature upon earth—namely, his immaterial and immortal spirit; and when we come to the contemplation of nature generally, we question, or doubt, the existence of the Great First Cause. These are the three steps which are most important to all true knowledge, and *all sound belief*; and we need not add, that if

the first one is not taken, it is utterly impossible to take any of the others; for though, in almost any matter, whether of thought or of action, we can begin without ending, there is not one which we can end without beginning. Unless, therefore, we admit a principle of action, different altogether from substantive matter, though revealed to our *senses* in that matter only, we lay a sure foundation for the most fatal error which the frailty of human nature can commit—we destroy our own immortal hope, and at the same time deny and contemn the Majesty of heaven; and under the influence of such an error, pretended morality is a cheat, and assumed religion hypocrisy, both used for selfish and dishonourable ends, as the thief avails himself of the cloak of darkness, under which to plunder his unsuspecting neighbour. It is even far worse than this; for, by this denial, we put ourselves from under the law of God in that mercy which He hath prepared for us, and as we cannot escape from the law, we become obnoxious to it in another form, that form which is in direct opposition to our enjoyment; to use a homely expression, we are like an uprooted tree, and must perish for ever, without the power of recovery, unless the kindly hand of the original planter shall in its mercy be pleased to restore us; and may add that, as with the tree, so with man, restoration delayed is altogether hopeless.

It must not be supposed, that the observation which we have now made is irrelevant to the first, or simplest act of formation in the mineral kingdom, because this is, in truth, our very first step in the philosophy of nature; and if we do not take it

rightly, the error will be multiplied in all the subsequent ones.

Having said this, we may observe, that that which we call a pure metal appears to be the very simplest existence of matter, of which our senses can take cognizance; for though in nature we find metals mixed with many other substances, and though in art, and also in the progress of nature, metals once pure, as far as our refining can purify them, mix with other substances; yet there is no case in which a pure metal has been resolved into two elements. When we say a pure metal, we must be understood as speaking with that limitation which is necessary to accommodate the imperfection of beings who see but in part; but still, as it is the beginning of our observation, it is necessarily the foundation of our knowledge.

There is an illustration of the fact of metal being the primary, or simplest form of tangible or perceptible matter, which, though there can be no absolute demonstration upon such a subject, comes as near to it as we could imagine, and nearer than, till within these comparatively few years, even the most profound and scrutinising of the human race could have supposed. The different earths, lime, clay, magnesia, silex or the earth of flints, and so forth, and some of the substances called alkalis—such, for example, as potass and soda—were long considered as simple substances, because they resisted the most powerful action of heat, produced by the combustion of fuel. But when the improvement of what is called galvanic apparatus had enabled a far more intense action to be employed, by the decomposition and the composition of water, all those substances

yielded to the new power, and the result, or the portion which stood proof against the utmost intensity of this extraordinary force, was a metal. Generally, we believe, those metals were obtained in a state of liquids or powders; but that circumstance did not render them less metals than they would have been had they been as hard as adamant. From the results of experiments on those metals, it is certain that some of the earths, and all the alkalis, are compounds of those metals with one or other of the component parts of water, one of which, when separated, is the lightest substance of which we have any knowledge, at the common temperature of the atmosphere; but the experiment is too delicate for enabling us to ascertain practically, whether the compound, as an earth, or an alkali, contains exactly the same weight as the primary metal, and the other parts of which it is composed. We are farther embarrassed by our inability to know whether, even in the utmost refinement of our experiments, we are able to get the substances on which we experiment, alone or in space absolutely void. Our organs of sense are complicated structures, both in the matter of which they are composed, and in their organisation; and, therefore, it would be vain to hope that their discernment can extend down to the distinction between the total absence of matter and its existence in the most elementary state. Our instruments are a little more simple; inasmuch as that, though compounded in their structure, they are not organised, and therefore they carry us a little farther; but even with them it is impossible for us to say how remote we may still be from the beginning.

There is, however, one mineral substance which

has not hitherto been so analysed, as to ascer that there is a metal in its composition. This stance is diamond, the hardest, the most brilli the most beautiful, of all known substances. usually known by the name of carbon, whic the Latin for charcoal, and it enters largely the composition of animals and plants, and of many rocks, and it also exists in small quantit atmospheric air.

We have no wish to quarrel about names; really as charcoal or carbon is not this subst in its pure state, it were better that it shoulc called diamond; because, among those substa to which we give the name of stones, diamoı the only one which has never been ascertaine be a compound. We cannot absolutely say hardness in a mineral is in all cases an eviden simplicity, but the diamond affords evidence of probability of such being the case; for diam as we have said, has not yet been ascertained t a compound of a metal with any other substa When it is subjected to the action of oxygen, of the component parts of the atmosphere, and of water, by being burned, it is wholly conve into heavy and poisonous gas known by the n of carbonic acid, and the weight of this aci exactly equal to the joint weights of the dian and the oxygen. There is no question that dian is formed by a natural process in not a very period of time. It is never found, as many c precious stones are, embedded in the rock, always in beds of clayey gravel; and at on the most remarkable districts in the world foı *production* of diamond, Pannah, on the table *of India, in the* province of Allahabad, the g

from which the diamonds are obtained is returned again into the pits; and the miners, whose ancestors have from time immemorial been employed in the same way (for it is a custom among the Hindoos that the child shall follow the same occupation as the parent,) all declare that at the end of fourteen or fifteen years the gravel is as rich in diamonds as ever. This is no doubt not the same kind of evidence as we would obtain could we see the diamonds in the progress of their growth; but as those miners make their livelihood by the sale of the diamonds, and are in the constant habit of practising what they allege, we cannot doubt the truth of the allegation. It is highly probable that the diamonds, which are thus formed by nature, are formed by the decomposition of carbonic acid; the oxygen of which is abstracted, by some process of nature with which we are not acquainted, until the power of aggregation of the primary atoms—or, as we call it, the power of crystallising in the carbon, or matter of diamond—so overcomes the dispersive power of the remaining oxygen as to drive the remainder off and leave the carbon perfectly pure.

We do not know the process of nature by which the separation is made, and this beautiful substance obtained in pure crystals; but as it is an operation similar to that of separating the metals from their oxides or combinations with oxygen, which we know how to perform in the case of them, it is an operation, in kind at least, within those limits to which real knowledge and practice in the arts may rationally aspire. It would be foreign to our purpose *to enter into* the details of operations, *because our object* is the elucidation of general

principles; but in some instances charcoal has been reduced to so hard a state as to scratch common glass. This was accomplished by exposing a quantity of it to the intense action of galvanic electricity—in condensed nitrogen, or that part of the atmospheric compound in which the common process of burning cannot be carried on; and as this operation made an approach to the production of diamond, we have only to suppose a greater intensity of galvanic action, and perhaps a greater condensation of the nitrogen, in order to arrive at the perfect diamond in a state of as great brilliance and purity as it is formed by nature.

We do not mean to say that diamond is a metal; but, in what we have now stated, that it follows the law of the metals; and it is, like them, a substance, which no known process, either of nature or of art, can reduce into more simple elements. We must therefore refer it, in a general point of view, to the same class of substances as the metals—namely, to those which are nearest to simple matter under no specific form. And there is something in the diamond which carries our information a little further: it is a general law in every kind of action upon matter with which we are acquainted, that an energy works more powerfully the more nearly that it works singly. It scarcely needs observation to establish the truth of this, though observation does establish the truth of it, as agencies are known only by their effects, when the one is different, the other must be different; and if we suppose two agencies to operate in the same case, each of them must necessarily be in so far an *antagonist* of the other, and thereby diminish its *effect*. Now as diamond is the hardest of all known

substances, and also one which, though it can be readily combined with oxygen so as to form an aërial fluid or gas, and also a component part of every thing that lives and grows, and of very many rocks, we may naturally conclude that carbon, as it exists in diamond, is more the result of one single combining energy than any other known substance. From this it almost necessarily follows that substances in the greatest degree of hardness of which they are susceptible, are hard nearly in proportion as they are simple. In this matter, however, we cannot be positive, because heat comes in as a disturbing element; and as it acts so differently upon different substances, we never can be able to ascertain how much of the consistency of any metal or mineral depends upon the power of union among its own particles, and how much depends upon the influence of heat. Experience shows us, however, that heat is in every case a repulsive force, tending to separate the particles of those bodies upon which it acts; and therefore we may in general attribute the greater softness of one body than another, to its greater susceptibility to the influence of heat.

Our next subject for consideration, in endeavouring to find out the method of acquiring a knowledge of the mineral kingdom, is the mode in which the different parts, or rather portions, of a homogeneous subject are brought together. We call a substance homogeneous—which means that all the parts of it are formed or made in the same manner—when a large and a small piece of it differ from each other in no other respect than size or shape; and we do this, *whether* the substance is simple or one *which we have* never been able to analyse into

parts different from each other, or whether it be composed of such that we can so analyse it. The more simple that it is, the more definite form it takes; but we must take this statement with some limitations; because the three states of solid, liquid, and gas, as produced by heat, and the different susceptibilities of different substances, simple or compound, by heat, interfere with the arrangements which the particles of matter would take if they were disturbed by no such agency.

We know nothing of the arrangement of particles, or atoms, either in a liquid or in a gas; because we can find no arrangement in them, nor can we distinguish a single particle from another by even the nicest examination. Indeed the consistency of each of those forms of matter shows us that in it no particular principle of arrangement has operated; because, except in so far as gravitation is concerned, all the atoms, or any portion, either of a liquid or a gas, can be moved in every direction with equal ease. When we come to solids, however, the case is different; and the primary form of a mineral solid, whether simple or compound, appears to be that which is called a crystal. There are indeed solids which appear perfectly homogeneous, or every where of exactly the same nature and consistency, which show no crystalline structure; but in general, if not in every case of these, there has been another element and another agency in their formation than that which is understood properly to belong to the substance which appears as a solid. Such solids have been dissolved in water or some other liquid, or in a gas, or they have been dissolved by the action of heat or some other agent, and their particles forced

together by too rapid or too powerful means for allowing them to assume that arrangement which they would have assumed had they been left undisturbed.

But, with proper allowances for the effect of other causes and the influence of other circumstances, we believe it may be assumed as a general truth, that the natural form into which every mineral substance could pass, if left free to those powers of union or attraction which may be considered as inseparable from its ultimate particles, though active and not substantive, is that of crystals.

In the preceding paragraphs we have made use of the words atoms and particles, and it is necessary for such readers as are not conversant with speculations like the present, to understand clearly what is meant by these words. The word "atom" literally means that which cannot be divided even into two parts; it is therefore the ultimatum of minuteness in every kind and form of matter; but from what we have already said it must be evident that it cannot be discerned by any instrument which we can employ; and far less by our unassisted organs of observation. The word "particle" has very nearly the same meaning, for it signifies the result of the ultimate parting or dividing of any substance. These are the original and proper meanings of the words; and they are the meanings as we have hitherto used the words in this chapter.

There are, however, other meanings of them; for we call the smallest possible portion of a compound substance that can exist, an atom or a particle: whether that substance consists of many elements, according to our notion of them, or of one only. We also give indiscriminately the name of atom

or particle to an exceedingly minute piece of matter, whether that minute piece is or is not divisible into parts similar in their nature to the whole piece and to each other. It is necessary to understand those different meanings of these two words; because it is only when we speak of the ultimate particle, which admits of no separation into parts, either by mechanical division or by chemical solution, that we use the term as descriptive of the most rudimental action of material substance.

Crystallisation is the name given to this first or rudimental action of matter, and the product of this action is a crystal varying in its shape in different substances, but the same, or reducible to the same by natural cleavage, in the same substance. When we speak of a crystal we do not mean a mass of any particular size. It may be of considerable magnitude, or it may be so minute as to be invisible to the eye, even when assisted by the most powerful microscope. Hence we cannot begin our observation at the beginning of nature's work; and thus our notions of the mode in which that work is performed are, and must remain, in a great degree conjectural.

A crystal is always a solid, whatever hardness or tenacity of parts it may have; and therefore, if we are to consider the original formation of a crystal, we must suppose the matter of which it is formed to have previously existed in a fluid state; and if we ascertain the form which it would assume in this state, if undisturbed by any action except its own, we shall make one step toward understanding the formation of the crystal. We must consider matter in every state as subject to the action

of gravitation as an attractive force, and heat under some of its modifications as a repulsive one; and the three states of bodies, solid, liquid, and gas, appear to be attraction superior to repulsion in the solid, the two exactly equal in the perfect liquid, and repulsion superior to gravitation in the gas; but how much the one may be superior to the other in any one substance, or what precise degree of liquidity answers to the perfect equality of attraction and repulsion in the substance, we cannot determine; and the determining of it being a practical matter, is not essential to our understanding the principle.

Now we know that the form which every liquid assumes, when left to the gravitation of its own particles, is that of a sphere, or globe; and we have every reason to believe that there are in the globe of the earth two axes, or rather two series of axes, each differing in position from the axes on which the earth turns round, and the one series crossing the other. That series which lies most nearly in the direction of the axis of rotation is magnetic; and the series which crosses it and lies nearly in the direction of the equator, is electric; but it does not appear that the position of either of these is constant, like the axis of rotation; and we might reasonably suppose this to be the case; for the axis of rotation depends on the quantity of matter in the earth, without any regard to its quality, and also on the degree of rotation. The other axes to which we have alluded in all probability depend upon the influence of the light and heat of the sun, both of which have different effects upon different substances, and different kinds and even different colours of substances. It will, per-

haps, be discovered at some future period, that terrestrial electricity (answering as the axis of its direction does to the average part of the world on the surface of which the beams of the sun strike perpendicularly) corresponds with the direct rays of the sun; while magnetism is polarised electricity—the same energy as the unpolarised, but having its properties altered by the change of its direction, just as is the case in the polarisation of that particular portion or modification of the solar energy, which we denominate light. The perfect identity of the action of both of these under certain circumstances, gives a strong presumption of the truth of what has just been stated, and in proportion as experiments are more carefully made, the probability is strengthened.

When we speak of the primary formation of a crystal, in such a way as that our account of it will apply to those crystals which we meet with actually existing, we must speak of it as taking place near the earth. Now the earth is both an electric and a magnet, and electricity and magnetism, in every case which has been observed, have a tendency to diffuse and equalise themselves every where. Not that they produce equal effects upon all substances, for their effects are as different as the substances on which they operate; but still they produce, or tend to produce, upon every substance all that influence which the substance is capable of receiving.

This being the case, it is impossible to imagine that any portion of matter can remain near the earth, without being both an electric and a magnet, or having energies within it disposed in the directions of two axes, or series of axes. Electricity and

magnetism, as well as every other natural action with which we are acquainted, show their effect by producing motion. Heat and light, as apparent to our senses or indicated by our instruments, may accompany this motion; and when it gets beyond a certain degree of velocity, they always do accompany it, and sometimes in great power and splendour, as we witness in the lightning, the flash of which is seen in a room with closed shutters, and with the eyelids closed, and the heat of which consumes the most stubborn substances, and melts the hardest rocks. It is probable—nay indeed it is certain—that these accompany the motion, or rather in fact are identical with it, even when they are not apparent to our senses; for it must be recollected that it is not the motion or the moving force that we see,—it is the effect, the change of place in that which is moved.

Thus we have two energies, or two modifications of the same energy, which must tell upon every atom of matter situated near the earth; perhaps it may be the same in every other body in the universe; but of these we know nothing except their distances, motions, magnitudes, forms, and quantities of matter taken as wholes. Each of those energies is revealed to us as producing motion; and it will be easily understood that there are two ways of considering every motion: it is motion *from*, if we refer it to its beginning in space, and motion *to*, if we refer it to its end in the same. Thus the force gives us the direction of an axis, the two poles or extremities of which stand in exactly the opposite relations to each other, the one as an attractive, and the other as a repulsive; or as it is

usually said, a positive and a negative pole. This is, as it were, a miniature of the grand principles of the attraction of gravitation and repulsion, and may be a modification of it; but the analogy has not yet been fully established. Enough has been done, however, to show us that when liquid matter near the earth is so far set loose from the agency which held it liquid, as that its own particles can become the chief instruments in determining its form, it is under the influence of attraction and repulsion; and therefore the smallest piece of it is formed as it were in the plane of an axis of some kind or other, or generally speaking, of two axes forming an angle with each other; and it is not a little remarkable that crystals polarise the beams of the sun in part, but not in whole, when those beams are made to fall in a certain direction to the plane of the axis. We can observe this crystallisation, and also the forms which different substances assume, in many experiments; but why each substance should have that peculiar form which we do find in its crystals, is another and more difficult matter.

We already mentioned the probability that a substance would take the most compact crystalline form, when its composition is the most simple; and we instanced the diamond as probably the nearest approach to simplicity of all minerals, hence the original form of the crystal of the diamond may be regarded as the nearest approach we have to a primitive crystal. This form is a figure of four sides, each of them an equilateral triangle, which happens also to be the most simple of all the regular solids. When we take a portion of a definite size, it is cleavable in the planes of its sides,

much more easily than across them; and thus we can reduce it to any number of small crystals that we please.

It does not follow, however, that every diamond which is found should have this shape, or indeed that any natural diamond should have it. Diamonds are formed in the earth, and so the matter of them cannot in any one case come equally in all directions to the point at which the crystallisation begins, so that after the first nucleus is formed, the subsequent formation may be made upon all parts alike, though this rarely happens; or it may be applied to them unequally, and even to one part of a face and not to the rest of it. Hence the diamond may be externally of any imaginable shape; but whatever it is externally, the cleavage is always in the direction of the planes of the primary crystal, and the stone can be cut or split upon any of these planes into thin laminæ or plates; but no art can thus split it in a direction across these. If the lapidary wishes, as he generally does, to cut it in directions not parallel to its planes of cleavage, he must saw it asunder, which operation is performed by the edge of a thin metallic wheel, which is sprinkled with diamond dust, and made to turn round rapidly while the diamond is held in contact with it.

Though crystals of different substances take different forms, yet it is true that the original formation of by far the greater part of the mineral substances which compose the solid portion of the earth, as far as we can examine it, is crystalline; and that when a mineral takes any other form than this, *that form has* been produced by some agency *external of itself,* and subsequent to its originally

becoming a solid. The last expression must, however, be taken with some limitations; for as a solid may be formed immediately out of liquids or out of gases, and as these may be mixtures the crystallising force of one part of which neutralises that of the other, the result may not be a crystal. The formation of those compounds is, however, rather a complicated subject, and can be understood only by those who are well skilled in the sciences of chemistry and minerals; therefore to enter upon them here would be out of place.

Mineral substances which are not in the form of entire crystals, and yet are solid masses, are held together by what is called the attraction of aggregation; and as when the aggregate consists of parts which are different from each other in kind, those parts are mechanically mixed, as we can see them in many species of mottled stone—granite for instance, which gets its name from having its texture granular, or composed of grains or little pieces of different kinds of matter—it follows, that this force of aggregation by which they are held together, is different in its nature from the force of crystallisation. It tells upon the masses of the several grains or pieces which are held together, and not upon the individual particles; and thus the texture is not everywhere the same, either in its appearnce, or in its qualities, as it is in the crystal. This aggregation may unite together detached pieces or distinct crystals of the same substance, as well as of different substances; for it is only a new formation that will incorporate with the crystal, and become part of it; and the resistance to union between two perfectly formed crystals of the same matter, is always great in proportion to the force

with which they are crystallised. This is the reason why crystalline substances are irreparably spoiled when they are broken; and it sometimes happens that in the course of the formation, a portion of some foreign matter may interfere, and prevent the perfect union, so as to form a flaw in the crystal. If, however, any matter not crystallisable under the same circumstances with the matter of the crystal be intimately mixed with it, the crystallisation will take place, and the foreign matter will appear as a colour in the crystal, of a different shade according to the nature of the foreign substance; but those coloured crystals, are never so perfect, that is, never so compact and hard as the pure and colourless crystal. It is impossible for us to say whether the most splendent diamond that exists is absolutely pure; because the accuracy of our balances is limited and not absolute; but still, what is called a diamond of the first water, which means a diamond reflecting the greatest possible quantity of light, is harder than any other diamond; and it is owing to its being more free of foreign substances, and therefore united more exclusively according to its own law, that does so reflect a greater quantity of light.

It is probable, that the crystals of all pure substances, and of all compounds which make transparent solutions in water, would be perfectly colourless did they exist; and indeed as every substance is resolvable into a gas, and those gases, when unmixed and sufficiently expanded, are always colourless, we have reason to believe, that every perfectly homogeneous portion of matter, whether crystal or not, *if any not crystal* could exist, would be colour-*less*. *We must* bear in mind, that it is not the

substance which is the agent in the production of the colour which we see in it; it is the light, and the substance is merely the passive subject; and it is where different parts meet each other, that the light is refracted, and the colour appears. We can convince ourselves of this, by examining a polished piece of any of those minerals which display different colours as they are turned round obliquely.

The metals, which in one form or other, may be said to be diffused through all solid matter, living or dead, have a strong affinity for, that is a tendency to mix with, very many other substances. They often do this to such an extent, that it is worth while to separate the other substance, in order to obtain the metal for economical purposes; and indeed, this is the way in which the far greater part of all the metals, which are so useful in the arts, are obtained. There are some exceptions,—of which gold is perhaps the most frequent, silver the next, and various others occur more rarely. Iron, though the most generally distributed, and and by far the most useful of all the metals, is very rarely to be found in the metallic state, or what is called native; and where it has been found, it is doubtful whether it has not been reduced from its ore, by lightning or by subterranean fire, much in the same way as men reduce it in their smelting furnaces. Indeed, we may perhaps say, that every metal which is found native, has been reduced from its ore; though this portion of the subject is rather beyond our depth, as we shall never be able to ascertain whether it existed first in the metallic state, or in combination with some other substance. *That belongs* to those earlier days of the work of *creation, which* preceded that on which man was

formed out of the dust of the ground; and as we cannot carry our own history up to our own origin, we must not appear to be wiser in the case of those substances which, compared with us, must be regarded as the elder-born.

When the proportion of metal that any mineral contains, is so great as to give a metallic value to the mineral, it is called generally an ore of the metal. In the case of the same metal, the other substances may vary greatly, and this requires much detail, as well as skill in treating the different ores, so as to obtain the metals in the best condition. But this again is technical matter, upon which we cannot enter.

When the quantity of metal contained in the mineral is not sufficient to give it a metallic value, the mineral is called generally a stone, and as it lies in the earth, whether in a large or small mass, or in an accumulation of fragments jumbled together, it is called a rock. The word rock, in popular language is, however, never applied to any thing, the principal substance of which, in part, consists of vegetable or animal matter, though the remains of both are found scattered through the substance of some rocks. These remains which are found in the earth, are called fossils; and the study of them, though there are many difficulties attending it, is exceedingly curious.

Those rocks always contain some metal when they are coloured; and from the fact of the bases of what we call the earths, and also of the alkalis which enter into the composition of rocks, being metallic, it follows, that there is perhaps no rock which *does not* contain metal. But the metals *which form the* bases of these are very different in *their characters* from the other metals; and th

instant they come in contact with the water, they combine with that with great energy, and intense heat and light; and therefore, we could hardly suppose any of them so to combine with the substance of a rock as to give it a colour; and indeed, they, with the addition of water, or at least the oxygen of water, compose the part of the rock which is coloured by the other metals.

It is highly probable that the colouring by the other metal takes place at the very instant, and by the very same action, as the converting of the more delicate metal into an earth or an alkali; and that, while the delicate metal lays hold of some of the oxygen of the water, forming the colourless part, —the more stubborn metal lays hold of a portion of the same oxygen, and produces the colouring matter, which is so very intimately blended with the other—producing it, too, momentarily as the portion of rock is formed.

Rocks, which form by far the largest portion of those solid parts of the earth of which we can obtain any knowledge, are exceedingly numerous; and the study of them becomes not merely one science, or one profession, but many sciences and many professions. If the object is to ascertain their common external appearances, and the mechanical uses to which they can be applied in the arts, as for building-stones, coping-stones, and all other purposes to which stone, unaltered by the operation of fire, is applied in the arts, then the science of them is called Mineralogy. If the object is to ascertain what changes can be produced on them by the action of fire, so as to make them as it were *new substances*, by giving them new properties, *then it is* necessary to inquire intimately into their *natures and* their composition, and find out the

means by which their several parts, if they are compounds, can be separated from each other. When this has been done, and every product of a first decomposition has been subjected anew to the test, and the parts of this tested again until human ingenuity can go no further, and when this has been done, the analysis, if not absolutely complete as regards nature, is absolutely complete as regards the ability of man. But after this there are two other steps to be taken, before the knowledge of those can be made available for useful purposes; the properties of every component part into which the compound mineral has been resolved, must be ascertained with the utmost nicety, in order to find out the new compound. This may be called Mineral Chemistry, which is but another name for the investigation of those secrets of the mineral kingdom which, though performed again and again in nature, are not naturally open to the observation of man, in the agencies or the mode of performance.

We may just mention one brief instance in illustration of this: that beautiful metal which we call brass, which is used for so many useful and ornamental purposes, and which is one of the most manageable of all metals, either by casting in a mould, or by fashioning and polishing with a tool,— that metal is a compound of two other metals, neither of which possesses its beauty, or, for general purposes, its usefulness. These metals are copper and zinc, the one of a dull red colour and very subject to tarnish, and the other of a dull leaden grey. Copper is tough, and admits of being both cast and hammered; its texture is also close, and on these accounts it is very useful for a great

number of purposes; but copper is very difficult to polish, or work to a smooth and level surface by the help of a file; while there is no metal that works so well in this way as brass does. Zinc is brittle and tender; and though it is used for a good many purposes, and resists the weather well, in as far as mere decomposition by the oxygen of the air is concerned, it is not durable. In short if we take general usefulness to man into consideration, neither of these is anything like so valuable as brass. Of course when we speak of "value" we have no reference to the price of the articles in the market; because value, in the proper sense of the term, depends upon the extent to which an article can be used, more than upon its market or money value, which, in the case of the more expensive articles especially, is frequently merely imaginary, and sometimes ridiculous. In this rational view of the use of metals, iron and brass are a thousand times more valuable than gold; and in the parallel case of minerals, common limestone or good paving-stone is of many times the value of all the diamonds and other precious stones that ever existed. These now rare and costly productions of nature no doubt have their uses to man as well as in the economy of nature; and their uses, not abused in the using, must be for good, because the divine blessing was pronounced upon the whole creation. But when we come to speak of use to man generally, we must take the average of mankind, and count that the greatest usefulness which is useful to the greatest number. But to return to our metals: copper and zinc are usually found combined with other matters; and the ores of these are very unlike the metals. The ores of

both vary in appearance according to the substances which are combined with the copper and to the proportions of the compound. Now we have to perform a double operation before we can obtain brass in the metallic state,—we have to get the copper and the zinc pure, and in the right proportions for producing the brass which we want, and then we have to consider them together.

This is one of the simplest cases of mineral chemistry, though a very useful one; and some of the others are exceedingly complicated, and demand the most laborious inquiries, and the most prolonged and skilful working. From the number of the substances and operations, and the intricacy of some of the latter, this is a part of the philosophy of nature, or more strictly speaking of the use of nature, which none but professional people can fully understand; but it is so curious and so useful that every one however humble in station ought to know something concerning it. Metals no doubt form the weapons of war among polished nations, and more human blood has been wantonly, or at all events causelessly, shed by them as instruments, and without enmity on the part of the shedders, against their unfortunate victims, than by any or all other means. But in these times, the light of science, led on by the bright morning ray of the Star of Bethlehem, is unsinewing the arm of war, withering it and depriving it of its strength, and the hour may be on the wing when the sword shall be beaten into a ploughshare and the spear into a pruning-hook, when nation shall lead no army and lift no weapon against nation, but when every man shall sit in peace, security, intelligence, *and hearty and happy* industry, under his "own vine

and under his own fig tree, and the statutes of the the Almighty shall be no more broken as they have been, or the precepts of the Gospel of Peace trampled under the feet of war-horses, red and reeking to the fetlocks in human gore; but when all mankind shall be one brotherhood in knowledge, in industry, in mutual encouragement, and in religion; and "the glory of the Lord shall cover the earth as the waters cover the channels of the sea."

When this period shall arrive, or whether the perverseness of the human heart will ever admit of its arriving in full perfectiou, it is impossible to say; but it is cheering to perceive that there is a progress; and hope once sown in a good soil is a flourishing and a fruitful plant.

In proportion as this state of the world is approximating, the metals will more and more come to occupy their proper place, which is that of being the implemeut of industry, and the tool of art; and when we look upon them in this, the proper point of view, for appreciating them, we as Britons have more reason to be grateful for the portion of earth in which our lot is cast, for the various causes which have given us knowledge, and taught our hands to labour, and thrown a protecting shield over us so that we might labour in security, than upon any other subject whatever of a merely temporal nature. Look around the country, and see the countless number of mines driven into the earth, the millions of tons of metal, the smoking furnaces, the trundling wheels, the sounding hammers, the all-powerful engines, the free and fast communications, and the many thousands of industrious and rapidly increasing population,—look

around and see these, and say whether Divine Providence hath not cast the lot of our heritage in pleasant places? Yet this is but a little:—survey the globe from Cape Horn to the thick-ribbed ice, and from the farthest east to the most distant west, and mark where you can find a civilised nation, or even a savage, who does not possess or seek to possess, the products of our manufactures in metals. The quantity sent to every part of the civilised world is far more than the whole that they could produce to themselves; and they have it not only far better, but also considerably cheaper, in consequence of that wonderful combination of metal and fuel, ready communication, long-continued internal peace, and a freedom and all its blessings as compared with other nations, we possess. Nor is it among civilised nations only that this desire exists; for when navigators visit the remote isles of the sea, the demand of the natives is still for that implement which gives to one hand the efficiency of a dozen; it is iron, be it in what form it may, which is sought above all other commodities; but if the iron is fashioned into a tool, its value becomes empires in the eyes of the savage, especially when just beginning to awaken into that civilisation which is soon to enable him to take his seat at the grand council-table of the nations, when the subject of consultation shall be, how the products of every varied land shall be best brought to the general market, so that each race of men may enjoy equally the advantages of the whole.

CHAPTER IX.

SYNOPTIC VIEW OF THE MINERAL KINGDOM.

THOUGH it is impossible, in a work professing only to be a sketch, to give the details of any one department of nature, yet as there are many existing works in which these details are given at large and with ability, it may be useful to present the reader with a summary glance, as brief as possible, which he can, according as he feels necessary, follow out in any department which he may require; and as a book of reference, we cannot mention a more valuable work, treating in brief, of the mineral kingdom, and of those chemical agencies which are the chief causes of change in the mineral kingdom, than DR. URE'S DICTIONARY OF CHEMISTRY, which is replete with most valuable matter, and arranged and brought out with great judgment.

In endeavouring to give a concentrated practical view of this kingdom of nature, we must follow some system; and the most natural order is the order of simplicity. There may be said to be three grand divisions: First, metals which we have said have never been decomposed or resolved into parts, though the greater number of them naturally exist in combination with other substances. Secondly, earths, which in every case are understood to be compounds, and to have metallic bases, that is, to consist of a metal, combined with some other substance, which entirely destroys the metallic character, so that the earth appears quite different from a metal. Thirdly, compound minerals,

which consist of the union of metals with earths and other substances, of combinations of the different earths with each other, and in the case of diamond, and probably of some others, though the fact is not yet discovered, of substances which we can neither consider as earths or as metals. To take into consideration the various compound substances, incorporated with minerals and affecting their appearance, to which the term acid is in many cases applied, and which are, generally speaking, compounds of different substances with oxygen or with chlorine, would be to involve ourselves in the whole science of chemistry, an entanglement which would render it altogether impossible for us to present any thing like a comprehensible view of the mineral kingdom in short compass. Therefore, we shall confine ourselves to the outlines of the three grand divisions, the names of which we have stated.

But before we advert even to these, it may be necessary to call to the recollection of the reader, that gravitation or weight is the test of matter, and the quantity of this gravitation, so to speak, is the measure of the quantity of matter. This can be determined in the case of any particular mineral, or other substance, by weighing it in a common balance against known weights as standards; and whatever is the kind of matter, we are accustomed to say, and warranted to say, that its quantity is the same, if it holds the same weight in equipoise. From this we get a first and simplest means of distinguishing one mineral (or, indeed, substance of any kind) from another, We suppose that we have equal bulks of them; and when those bulks are *weighed by the* same weights, the results *give us their quantities* of matter in equal bulks or

volumes. These are called their specific gravities; because the gravity is different in every species of substance, or at all events each of these is the expression for the quantity of matter in a certain bulk or volume of the substance, compared with some standard, which standard must be invariable. It is of no consequence what the bulk or volume is, provided that it is the same in all the substances that are compared; for the fact which we wish to establish by their comparisons is not the quantity of matter in any piece of any particular kind of matter, but the relative proportions which different substances have to each other, in respect of quantity of matter.

In order to arrive at a knowledge of those proportions, we must have a standard, which standard it is most convenient to represent by the number 1; because this enables us to express the proportions of the specific gravities in the smallest possible numbers, and thereby renders the arithmetical operation to which we must come in every practical case, the simplest possible. The particular substance which we make use of as our standard is a matter of no very great importance; but it should be one which is generally accessible, and as little liable to change by the operation of natural causes as we can obtain. Water answers well in both of these respects. Mankind cannot live, neither can there be any vegetables or any animals, where there is no water; and therefore water has the property of being accessible every where. It is also less liable to changes of bulk than most substances; for though it passes into vapour or steam with not a very high temperature, and crystallises into ice at not a very low one, yet in all the

range of temperature from freezing to passing into vapour, there is very little change in the bulk or volume of liquid water. There is a little, however; and in very nice experiments, this little renders it necessary to take into account the temperature or degree of heat in the water when taken as a standard, but for all common purposes it is quite sufficient to refer to pure water as a standard, without going minutely into the investigation of difference of temperature.

In comparing minerals with each other, in respect of their specific gravities, or quantities of matter in equal volumes, we thus take water as a standard, and express it by the number 1. If any other substance is weightier than water, it will be expressed by a number greater than 1; and this number will either contain a fraction or part less than 1, or not, according to circumstances. If on the other hand the substance is lighter than water, it will be expressed by a fraction less than 1; and when the weights of equal bulks of any number of substances, as compared with an equal bulk of water, are found by experience, and the numbers for them are expressed, we are in possession of a table of specific gravities.

The knowledge of this doctrine of gravity is of more consequence in the philosophy of nature, and especially in understanding the order of position in some mineral substances, as they are found in a state of nature, than one would, at first sight, be apt to suppose; for in a collection of substances of different specific gravities, if they are free to move, the heavier ones will find their way nearest to the centre *of the earth,* and the lightest ones will find *their way furthest* away from it. There is a beau-

tiful exemplification of this, in the consistency of some sandstone rocks, which contain pebbles or pieces of matter heavier than the average of the rock itself. Where these formations have been formed under rolling waters, as under the waves of the sea, the top of one formation is always furrowed, which is done by the vibration of the waves; and after it is done, the furrow determines the vibration of every future wave; and thus, if there is no new deposit of matter, these furrows may preserve the same form for a considerable length of time. If, however, the water over them brings a new deposit of sand and gravel, the largest masses of the gravel fall soonest to the bottom, and the descent of the others is smaller and smaller in proportion as their size lessens. In this way the downward flexures at the surface of the under deposit, contain the largest pebbles of the deposit immediately over it; and the grain of the stone gets finer and finer as we come upward through this second deposit, until at the top it becomes so fine, in some instances, as to be hardly discernible.

METALS.

Metals are very numerous, but when pure, they all have a lustre which cannot be mistaken. They can all be melted by heat, which does not render them transparent, or destroy their lustre. Many of them are malleable, or can be beaten with a hammer, drawn into wire, and otherwise worked into form. They combine with very many substances, the most active of which are oxygen, chlorine, and iodine; and this, whether it be attended *with great* light and heat, or not, may be con*sidered as* the combustion or burning of a metal.

The result of this operation is called an oxide, a chloride, or an iodide, according as one or another of these substances is combined with a metal. They also combine with each other when melted, and form what are called alloys, of which brass, already alluded to, is a specimen. With only one, or at most two, exceptions, they are susceptible of electric action, and all of them are capable of existing in the three states of solid, liquid, and gas, though the different ones pass into those states at very different degrees of temperature; but of those which are popularly known as the metals by way of eminence, there is only one which is liquid at the common temperature of the atmosphere. This one is mercury, or quicksilver; and even it becomes not merely a solid, but a solid which can be hammered, if it is exposed to sufficient cold. At the extreme north of North America, the natural temperature of the atmosphere is so cold, that mercury exposed to it would remain solid for several months every winter.

Besides their uses in the arts, considered singly as materials, the power which we have over metals in fashioning them into any shape we please, and their durability, render them among the most valuable productions in nature. Their value is farther increased by the readiness with which they can be combined with each other, and with other substances; though the latter is sometimes a disadvantage, as the combination destroys the brightness of the metal, and in time converts it into an earthy mass. This imperfection is called rusting; and, as already mentioned, the chief agents which produce it, are oxygen, chlorine, and iodine, and compounds *into which these enter* as ingredients; and as these

are the most active substances in nature, we find them in combination almost every where.

Twelve of the metals are malleable, though they possess this quality in very different degrees. The following are their names and specific gravities, it being understood that the part of the number before the point means so many times the weight of an equal bulk of water, and the part after the point means so many hundredth parts of an equal bulk of water:—Platinum, 21.47; Gold, 19.30; Silver, 10.45; Palladium, 11.80; Mercury, 13.60; Copper, 8.90; Iron, 7.70; Tin, 7.29; Lead, 11.35; Nickel, 8.40; Cadmium, 8.60; and Zinc, 6.90.

Platinum, the heaviest of the metals, is also the most durable, or least acted upon by other substances; and it bears a stronger heat than any of the rest, though it can at last be melted, but not by the heat of common furnaces. The heat produced by the violent action of oxygen and hydrogen is the only known chemical action by which platinum can be melted; and when it is thus melted, it is less heavy, that is, has less specific gravity, as cast platinum, than when it is hammered; but this is a property common to all malleable metals. Platinum can be welded, that is, two pieces of it can be united, without any solder or cementing substance, if they are properly heated; and iron is the only other metal which possesses this property. Platinum is found in various parts of the world, and its ore is generally compounded of ores of a great many metals. It was first brought from South America; but it is far more abundant in the metallic district in the north east of European Russia.

Gold is the most celebrated; and, generally *speaking*, the most costly of all the metals. It

cannot be welded; but it is malleable and ductile without limit, and it is soft when pure; and as very few of those combinations of the active solvents formerly mentioned, which occur in ordinary circumstances, are powerful enough for acting upon gold, it retains its lustre, even in the open air, for a long period of time. When gold is dissolved in any strong preparation of the active solvents, it can be got out again, by introducing almost any other metal; because in chemical actions, the stronger always overcomes the weaker. Thus, those who work in gold can always get back the particles of it, however small, if they retain the substances in which they are contained. When gold is thrown down from a solution by ammonia or hartshorn, the precipitate, for it is a compound, is called fulminating gold; and it explodes with such force, that the smallest possible quantity of it is dangerous. Gold furnishes a beautiful purple colour for enamel painting; and, indeed, independently of its commercial value, gold is a very interesting study and a very useful substance. It is found in various parts of the world, sometimes perfectly pure, and sometimes mixed with silver and a little iron; but it is never found in the state of an oxide, a chloride, or an iodide; because none of these singly will dissolve it. The solvent is oxygen and chlorine united; and it is readily procured in the arts by mixing nitric and muriatic acids; or, as they are called in common language, aquafortis and spirit of salt, the first of which supplies the oxygen, and the second the chlorine.

Silver is perhaps the most brilliant of all the metals. It is harder than gold, and very malleable, *but inferior to gold* in that respect. Silver forms a

fulminating powder with ammonia, as well as gold does; and though the explosion of an equal quantity is not so tremendous as that of gold, yet it is too violent to be applied to any useful purpose. Silver is a very useful metal; it is handsome, cleanly, wholesome, and far more durable than gold; but the uses of it are so familiar that it is unnecessary to detail them. Silver is found in many parts of the world, sometimes pure, sometimes in combination with other metals, and sometimes as an oxide; and one of the most frequently occurring of its ores, is a combination with sulphuric acid.

Palladium is a metal of the same greyish white colour as platinum; and it is very tough, and works well with the hammer, or draws into wire. It is little changed by exposure to the fire, unless the heat is raised to a considerable height. It is soluble in those acids which do not act upon platinum; but they do not completely dissolve it; and the solution is red. It has hitherto been found only in Brazil, in small quantity, in a metallic state, but combined with a very small portion of platinum, and iridium, another rare metal, of great weight, but not malleable. It might be used for some purposes in the arts, but the quantity of it is very small, and it has no beauty, or other quality, to recommend it, superior to that which is possessed by some more plentiful metal.

Mercury, as already hinted, differs from all other metallic substances, in remaining fluid until a degree of cold is produced, equal to thirty-nine below 0, or zero, in the common thermometer, which is seventy-one degrees below the temperature at which water becomes a solid. It does not require a very high temperature to convert it into vapour,

and when this is done with access to a sufficient quantity of oxygen, a red compound of the two is obtained. Mercury, from the ease with which action takes place between it and other substances, enters into a great many combinations; some of which are used in medicine, and others as colouring matters in painting. Calomel, or the proto-chloride —which means, that there is less chlorine in the mixture than when the two ingredients are freely exposed to each other—is a very active medicine, and recent experience shows that it is not only safer, but more powerful when exhibited in very small doses. Corrosive sublimate, the compound formed by mercury and chlorine when freely exposed to each other, under the influence of heat, is a deadly poison, though there are many operations in the arts in which it is highly useful. It is indeed worthy of remark, and equally worthy of admiration, that there is no powerful production of nature which is not as useful as it is powerful, when its nature is understood, and it is used with due caution. The principal colouring matter, or pigment, obtained from mercury, is vermilion, which is of a very beautiful red colour; but that which is found native in the mine is far superior to that which is formed by art. Mercury is found in many parts of the world, sometimes as fluid mercury, sometimes combined with silver, sometimes with sulphur, and sometimes with a number of other ingredients. Working mines of mercury is an exceedingly unhealthy occupation, and it is unhealthy in proportion as the mine is rich. It enters into the system, producing the same effect as too great a quantity given as medicine; and as the giving is continual to the poor miner, he speedily loses his teeth; then he becomes diseased; and, in a short time, he falls a victim to

his occupation. Mercury enters very rapidly into combination with silver, and still more so with gold; and though this tendency of it makes it a very dangerous substance to be near those metals, or articles made of them; yet it is of considerable importance in obtaining the metals themselves from those substances with which they are mixed. It forms an amalgam (which is a name given to an alloy of mercury), with the gold or silver, but not with the other substances, even though metallic, wherewith these are mixed. Gold, silver, and mercury are specifically heavier than almost any other substance; and thus, if the matter which contains the gold or silver is reduced to powder, mixed with the requisite quantity of mercury, and then well stirred in water, the alloy falls to the bottom, and the remaining matters can be washed off. After this, the mercury is driven off by heat, and the gold or silver is obtained in a state of purity.

Copper has been already alluded to, and its appearance is too well known for rendering any particular description of it necessary. Copper is a durable metal when exposed to the air; for though it very soon tarnishes or rusts on the surface, yet the rust is so hard and adheres so closely, that it forms a protection to the remainder of the metal. Copper enters into combination with most of the active substances, and with several of the metals. But all these combinations of it are poisonous, and even the metal itself has a nauseous taste. Unless the greatest cleanliness and care are bestowed, copper is an exceedingly dangerous material of which to form cooking vessels, especially vessels in which vegetable substances are to be kept. The combination, or salt, which copper forms with

acetic acid—that is, with vinegar—is the delicate green colouring matter known by the name of verdigris, which is very poisonous; and therefore if any substance containing this acid is cooked in a copper vessel, a poisonous quality is sure to be imparted to it. Some of the other salts of copper are finer in their colours than this one, but they all have the poisonous quality. Copper is sometimes found is very nearly a pure state, being only alloyed by the least trace of gold and iron. It occurs also as an ore mixed with various substances, and often very brilliantly coloured. It is found in many parts of the world, and is especially abundant in Cornwall and some parts of North Wales; and in many parts of the western side of South America, it repays the labour of the miner far better than either the silver or the gold which are found in the same districts.

Iron was mentioned at some length in the preceding chapter; so that we shall only now mention one or two of the states in which it is found. It is diffused every where, not only as the colouring matter of rocks, but in such quantity as to be available for useful purposes, if the people have sufficient knowledge and skill for working it. No one can help admiring this general distribution of iron over the surface of our globe, or fail to perceive in it a very striking instance of that beneficial adaptation, whereby the Creator has fitted the world for his rational creatures. Iron is a metal of universal application, and it is at the same time a metal found every where. There is something more extraordinary even than this in the furnishing of iron, for it occasionally drops down *from the sky.* In various ages and parts of the

world there have fallen to the earth, often in a state of great heat and with vast velocity, as if they had come from a great distance, masses of matter known by the name of meteoric-stones. Of these the greater part is always iron, never less than nine tenths of the entire mass, and sometimes the iron is pure. When not pure the remainder of the mass is nickel, another metal; and the fact of those meteoric bodies containing nothing but metals, gives at least some colour to the opinion which we formerly hazarded, that metal is in all probability the primal state of solid matter. Be this as it may, some of those masses are of great size; and, in particular, one fell in the province of Bahia, in South America, of the enormous weight of fourteen thousand pounds. It was seven feet in length, four feet in width, and two feet in thickness. It contained nickel, and the iron was regularly crystallised, though the crystals were firmly aggregated into one mass.

These meteoric-stones have fallen, and have been remarked as extraordinary phenomena, from the remotest antiquity. We have them recorded nearly fifteen hundred years before the birth of our Saviour; and in proportion as the people of different nations have had more communication with each other, and have thus collected the phenomena of different parts of the world, the number of recorded ones has increased. We are therefore to regard the fall of meteoric-stones as one of the regular phenomena of our globe; but they appear to have no connexion with the particular places upon which they fall; nor is it possible for us, as we see them only in the very last stage of their descent, to say whence they come or how they are

formed. That they are formed somewhere within the sphere of the earth's attraction we may naturally conclude, because if they were formed within the sphere of the attraction of any celestial body, it is not easy to conceive by what means they could escape from under the dominion of its attraction, and get under that of the earth. Many theories, or rather hypotheses, have been advanced respecting their origin,—such as that they have been discharged by volcanoes, or shot from the moon, or that they are fragments of shattered planets, wandering deviously through the system, as motes dance in a sun beam. But all these hypotheses are equally true and equally false, inasmuch as we have no means of arriving at the facts of the case. That the stones are the products of terrestrial volcanoes is very unlikely; because the matters discharged by volcanoes never are, or in the nature of things can be, crystallized, inasmuch as those matters are discharged in a high state of ignition, a state in which no known substance crystallizes. It is just as unlikely that they should come from the moon: for the most careful observations which have been made on that luminary lead us to conclude that it contains on its surface no such small fragments as even the largest of these. Our wisest plan, therefore, is to follow the matter no farther than direct observation bears us out, and candidly to confess our ignorance when we come to that stage of it of which we can have no knowledge.

The native iron, which appears to have decidedly a terrestrial origin, is always mixed with a small portion of lead, and a still smaller portion of copper. It occurs in masses, in plates, and in thin leaves; *it is malleable, without* reduction, and always mag-

netic. This is an alloy of iron, though the other metals are in such small quantity that the iron gives the predominating character of the whole. The ores of iron are so very numerous and so varied in their appearances, that a particular description of them would occupy much space. One class of them, and those which are the richest in matter and the most valuable to the manufacturers of iron, consist of iron mixed with oxygen, and generally with one or more of the earths, and sometimes with other metals. But iron also occurs in the state of salts, formed by the union of iron with one or other of the acids. The sulphates of iron, or compounds of iron with sulphuric acid are generally of a brassy colour, more or less bright, and but little liable to be tarnished by exposure to the atmosphere. They are known by the name of pyrites, on account, we believe, of their inflammability; and there have been instances in which ignorant persons have kept them with great care, in the belief that they were masses of gold. When mixed with water, and exposed to the air the sulphate of iron dissolves in the water, and again crystallises; and this is the way in which the green sulphate of iron, known under the name of green vitriol, and used for many purposes in the arts, is usually obtained. When there is not a free exposure to the atmosphere, and water is admitted to this salt of iron, the decomposition of the water is often so rapid and so violent as to produce actual combustion; and burning cliffs burning fissures of the earth, and the setting of coal mines on fire by an injudicious management are often produced by this species of action. It would be endless, however, to enumerate all the

circumstances connected with iron as a metal, as occurring in the mineral state, as forming part of the blood of animals, and as being apparently produced in the air in those meteoric bodies to which we have alluded.

Tin is a metal so decidedly British, though Britain is not the only country which produces it, that it is sometimes supposed to have, in part at least, given name to the island; and the general opinion among antiquaries is, that a traffic in tin was carried on from the Levant to Britain long before the invasion of the country by the Romans. The colour of tin is yellowish white, and though not so heavy as lead it is much harder. When bent it emits a peculiar crackling sound; and though in itself it gives very little sound on being struck, it adds greatly to the sonorousness of copper, in that compound or alloy to which the name of bell metal is given. It is not tenacious, but nevertheless it is very malleable, for it can be beaten easily into leaves of tinfoil as they are called, a thousand of which would not exceed an inch in thickness; and it might indeed be beaten into leaves of only half this thickness. Its oxide is more difficult to be melted than that of any other metal; and therefore it is exceedingly useful in forming a white enamel, when combined with glass. The metal itself is used for very many purposes in the arts, not the least important of which are the tinning of vessels of iron or copper, and what is called the silvering of looking glasses. In the latter operation there is mercury placed between the glass and the leaves of tinfoil; and the whole are placed on a sloping table, and loaded with heavy weights, by which means the tin is pressed firmly against

the glass, and the mercury is reduced to an exceedingly thin but continuous pellicle, protected from the air by the glass on the one side, and the tinfoil on the other, so that it preserves the brilliance of its lustre without tarnish, and the reflecting surface of the mirror is really a surface of pure mercury. As a metal, tin is seldom used pure, but generally in that state of combination which is called pewter. If this pewter is of the very best kind, the other ingredients ought not to amount to more than a twentieth part of the whole mass, and they should be zinc, copper, and bismuth. Tin so amalgamated forms what is called Britannia metal; and when the compound is skilfully made, it is very firm and hard, scarcely inferior to silver in beauty, and remarkably wholesome for domestic utensils; but it is rare indeed that we meet with it in this state of purity. It is generally mixed with a large proportion of lead, which gives it a dull bluish appearance, and vessels made of it are soft and very liable to tarnish.

Lead is a well-known metal, of a bluish white colour, not quite so fusible as tin, though it melts at a moderate heat. It is very soft and flexible, though not so tenacious as to be drawn into wire. It admits, however, of being drawn into pipes when kept hot, and also of being rolled out into sheets, in both of which states it is extensively used in the arts. It agrees with copper in one respect, that though the surface of it very speedily tarnishes upon being exposed to the air, the oxidised surface forms a protecting crust, and prevents the action of the air from penetrating farther into the substance, and thus it lasts for a long time as a covering for roofs, or in other situations exposed to the

weather. The oxides, or salts of lead, are, generally speaking, poisonous; but they are of great use in the arts, especially in the art of painting. When lead is dissolved in nitric acid, and precipitated by potass, the yellow protoxide is obtained; and if sublimed, or raised in vapour by the action of fire, it is partially vitrefied, or converted into glass; and in this state it forms what is called litharge, which is of a dull bluish colour, but forms, with oil, an excellent paint, and one which dries very speedily. When it is combined with carbonic acid, it forms what is called white lead, a material generally used for giving body to paints, and one which, from its drying quality, exerts a healing effect upon wounds in the skin; but it is at the same time of so poisonous a nature, that the men who are employed in the manufacture of it, are bribed with very high wages, and take a quantity of medicine, generally castor oil, every day, and even then they seldom live longer than a few years. If the yellow oxide of lead is exposed for about two days to the reverberating flame of a furnace, it passes into the red oxide, or red lead, which is also useful as a paint, as it has a strong body, and its colour is durable. It is remarkable that, while lead resists the action of the strongest acids, unless they are heated, acetic acid, or vinegar, acts powerfully upon it. The result is a crystallised substance in the form of needles, known by the name of sugar of lead, from its sweetish taste. It is a deadly poison; but, like most of the salts of lead, it is valuable as an external application, from the property which it has of coagulating the lymphous juices of the body, and thereby drying up ulcers and other discharges. Sugar of lead is a *pure acetate of lead*; but the sub-acetate, known by

the name of Goulard's extract, is the most valuable for healing purposes. It is formed by boiling litharge in vinegar. White lead is made by rolling plates of lead like a scroll, leaving about an inch of space between the folds, and placing them in earthen pots, in the bottom of which strong vinegar is put, and then the pots are covered, and exposed to a moderate heat. By this means, a portion of the surface which is exposed only to the fumes, becomes converted into white matter, which breaks off in scales when the plates are unrolled; and the plates are repeatedly treated in this manner, till they have no longer sufficient strength for standing erect in the pots. The fumes which arise in this process contain a considerable quantity of acetate of lead; and it is this which renders the process so dangerous to the workmen. From what has been stated, it will readily appear that lead must be used with great caution in all cases where there is any chance of its combining with acetic acid. This acid is contained in almost every vegetable substance, and more or less in all fermented liquors prepared from vegetable matter; and therefore vegetables ought never to be dressed, or fermented liquors used, in leaden vessels. Those who deal in wines are sometimes in the habit, when their wines turn sour, of restoring their sweetness by litharge, or some other salt of lead; but this process is a most iniquitous one, as the wine is thereby converted into a poison. Cider, which is the fermented juice of crushed apples, contains a great deal of acid; and if it is made in leaden vessels, or even kept in them, it is very poisonous. The dangerous quality of lead *when used* as vessels may, however, be counter*acted by* alloying the lead with tin, or convert-

ing it into pewter; and half the weight, or even less, of tin, though it will not make a beautiful metal, will make a wholesome one.

Zinc is of a bluish white colour, somewhat brighter than lead; it is much harder, and though not easily broken by a blow of the hammer, it cannot be much worked by that instrument. It can, however, if raised to a temperature somewhat exceeding that of boiling water, be rolled into plates, drawn into wires, and otherwise fashioned for useful purposes. It melts before it burns; but when it is made red hot, it combines so rapidly with oxygen, as to form a flocculent substance of a white colour, which is known by the name of philosophical wool. When burned in chloride, it forms a semitransparent compound of a whitish colour, which is as soft as wax, and melts at about the same degree of heat as water boils. It is an exceedingly acrid substance, and instantly destroys the skin on being applied to it.

The ores of lead and zinc are very common in many parts of the British islands. Lead most usually occurs in the form of metallic crystals, and generally with a small admixture of some other metal, not unfrequently of silver, which is sometimes in such quantities as would be worth extracting. The crystals of the ore are, generally speaking, cubical, and their lustre exceeds that of the metal itself; but still they contain so much sulphur, that if exposed to a strong heat, they would burn instead of melting, and therefore the sulphur, has to be driven off by the slower process of roasting. The ores of zinc are generally in the *state of* sulphate, of a brownish colour, *and with metallic* lustre. They are usually termed

blende, and they occur most frequently in lead mines, intermixed with various proportions of iron and other metals; but the zinc always predominates, and next to it the sulphur.

Nickel is a very hard metal, and intermediate in its colour between tin and silver. It has a strong attraction for other metals, and therefore it is difficult to purify. Like iron, it is magnetic; and it is the metal which is chiefly found combined with iron, in meteoric stones. It is malleable both cold and hot, and not much affected by contact with the atmosphere. It is understood that arsenic, and also copper, destroys the magnetic power of nickel. Nickel is not a very abundant metal. It is found native in the mines of Saxony, though combined with a little cobalt and arsenic, and of nearly the colour of brass. It is also found in ores of a copper colour of a greyish black, and apple green.

Cadmium is a metal of a beautiful white colour, capable of receiving a high polish. It is not much subject to tarnish when exposed to the air, and it admits of being hammered, though if that operation is long continued, it comes off in scales. Cadmium is found more frequently along with zinc than in any other situation; but it is so volatile that it escapes in a vapour.

The metals which we have enumerated are the only ones which admit of being hammered into shape, with the exception of some of the metallic bases of the alkalis and earths; and these are so easily soluble in water, that they could not be used for any useful purpose, neither do they exist in nature in a separate state. There are, however, *many metals* not malleable, which are found in the *state of ores*, or as metallic; and which are useful

both in forming alloys with other metals, and separately in many processes in the arts. The metals which are not malleable, and whose oxides exist in their ores, are about fifteen in number, but there may be many more which have not hitherto been discovered. Their names and specific gravities, so far as known, are:—Bismuth, 9.88; Antimony, 6.70; Manganese, 8.00; Cobalt, 8.60; Tellurium, 6.11; Arsenic, 8.30 (but subject to variation); Chromium, 5.90; Molybdenum, 8.60; Tungsten, 17.40; Columbium, 5.60; Selenium, 4.30; Osmium (indeterminate); Rhodium, 10.65; Iridium, 18.68; Uranium, 9.00; and Titanium, and Cerium, the specific gravities of both of which are also indeterminate.

Some of this numerous list of metals are so rare, that they could have no interest to a general reader; and therefore we shall confine our remarks to one or two of those which are most useful in the arts.

Bismuth is a metal having a peculiar colour, varying between yellowish and reddish white. It is harder than lead, and can scarcely be said to be malleable, a blow of the hammer readily breaking it, and even reducing it to powder. It melts at a comparatively low temperature, and burns with a faint blue flame. From its brittleness it cannot be used singly for any useful purpose to which metals are applied, but it enters into several useful compounds, such as printing types, and various other articles. When mixed with an equal weight of lead it forms a white alloy of a brilliant colour, which is harder than lead, and more malleable than bismuth, and an additional proportion of lead increases the malleability. Some of the alloys of bismuth with

various metals, have remarkable properties. Thus, for instance, eight parts bismuth, five lead, and three tin, compose a metal which can be melted in a piece of stout paper over a candle, without burning the paper. Bismuth is also an ingredient in the solder used by pewterers. The object of all solders is to have them more fusible than the metal which they are to unite together, and yet at the same time as nearly of the same hardness and colour as possible. The pewterer's solder is made of five parts lead, three tin, and one bismuth, the object of which is to increase the fusibility, and at the same time the hardness of the other two. The oxide of bismuth is also used in medicine; but like all metallic medicines it requires to be administered in small doses, and very cautiously. Bismuth is found nearly pure, in veins in micaceous slate, in which state it occurs in several parts of Cornwall. It is also found in the state of glance, or compound ore, in which it is united with various substances, not unfrequently with sulphur.

Antimony is of a dusky white colour and scaly texture; but the name of the metal is in commerce given to the ore, which is a sulphate, and is called crude antimony, the pure metal being styled the regulus. Antimony is too brittle for being used alone for any of those purposes to which metals are applied, but it is very useful in various compound metals to which a portion of it gives additional hardness, and also another property which is very valuable for some purposes, namely, that of expanding in cooling. All metals and other substances which, in cooling, pass into a homogeneous mass, in which no distinct crystals can be detected, shrink from the mould, or contract in their dimensions, and

thus never give a sharp impression to any figure which it is desirable that the mould should impress upon them. This imperfection is remarkably the case in glass; because unless the crystalline structure is prevented from forming, by the slow process of cooling, called annealing, it becomes so brittle, that the fall of a grain of sand would shatter any vessel to pieces, while many would break spontaneously from the mere changes of the atmosphere. Thus, in the present state of our knowledge of the properties of glass, it is utterly impossible to obtain glass sufficiently strong for being useful, and at the same time so standing up to the mould in cooling, as to produce a sharp impression; and whoever shall succeed in producing a glass having those properties conjoined, if such a combination is possible, will reduce the expense of ornamented glass to a small fraction of what it is at present, and furnish the public with an article more durable, and far more beautiful than the cut glass now in use. Perhaps, however, from the nature of the substance, this is a hopeless desire. But to return to antimony, the subject under consideration. It is desirable that printing types, which are among the most valuable, and the most in demand of all human contrivances,—it is desirable that the type should stand firmly up to the matrix or mould, in which the face of it is cast, and that it should have a sufficient degree of hardness to resist wear in the face, from the operations of inking, printing, and washing. Now, it is found that a portion of antimony ,equal to about one-sixteenth part of the lead which forms the body of the type metal, gives additional hardness to the type, and additional sharpness to the face of the letter. A sort of coarse

plates, upon which music is usually engraved, or rather stamped, is also formed of an alloy of tin with antimony; and this is a much harder metal than the tin in a pure state.

The oxides of antimony are exceedingly active substances, and some of them are of great use in medicine. One of the most generally used of these is a triple salt composed of antimony, potass, and tartaric acid. It is used for cleansing the stomach; and though it is poisonous when taken in any quantity, and may be used externally for blistering the skin, it is yet an excellent medicine, administered with skill. Some of the compounds of antimony are also used in the printing of cotton goods, and, indeed, though the simple metal is of little or no use, the preparations of it are highly valuable. From its activity, antimony is not so often found pure in the mines as some other metals; and native antimony often contains a little silver, and also a little iron or arsenic.

Manganese is a metal of a dull whitish colour, but cannot be preserved in the air for any length of time, because of the tendency which it has to combine with oxygen. Manganese cannot be applied singly to any purpose for which a metal is used; but it is useful in many operations in the arts; it mixes in fusion with almost every metal except mercury. Gold is more easily melted when a small portion of manganese is combined with it, and it improves the ductility of iron. With copper its effect is different, for it renders that metal less fusible, and much more liable to tarnish. Manganese is also used in the manufactures of colourless glass, and for various other purposes; and its value in the arts depends partly on its own activity, and

partly on the great quantity of oxygen which its oxide contains, and which can be very readily separated by heat. The ore of manganese is called "black wadd" by the Derbyshire miners, in which county it is very abundant. Its colour is dark brown, and it has a brittle earthy appearance, occurring in lumps and in powder, but always reducible to the latter without much difficulty. If the powder of this ore is mixed with any of the fixed oils, with linseed, it soon becomes very hot, and at the end of about half an hour bursts into a flame.

Besides its uses to the glass maker and the potter, manganese is of great use in the art of bleaching, or discharging the natural colours of vegetable substances with the least possible injury to the texture. The manganese is not applied directly to the stuff intended to be bleached, but is used in procuring chlorine, the active agent in discharging colours, by means of sea-salt, or of liquid muriatic acid, or spirit of salt. When even a gentle heat is applied to either of these mixtures, the other ingredients combine, and the chlorine is set free in the state of a gas; but it is generally combined with lime before it is applied to use. The oxides of some other metals besides manganese, answer nearly as well for this purpose; but manganese has the advantage of being cheap and easily applied to use; and therefore it deservedly gets the preference.

Cobalt is a metal of a reddish grey colour, rather soft, and very brittle, but not easily melted. It is usually found combined with iron, copper, nickel, and arsenic, from which it is not easily separated. Cobalt is of comparatively little use as metal; but some of the mixtures of cobalt are of a beautiful blue colour. The most remarkable is with glass

which, when mixed with alumina or the earth of forms a beautiful blue paint. Cobalt is also much in imparting a fine blue colour to the body of g or to enamel, with which potter's ware is cove and in either case there is no metallic oxide w conveys nearly so fine a blue. Cobalt is obt in ores, of which, however, it seldom, if ever, f more than one half, the greater part being gene arsenic, and sometimes in the crystallized water in a considerable quantity.

Tellurium is a greyish white metal, very liant when fresh; but easily broken and dissi into fumes with a very moderate degree of hea has not, hitherto, we believe, been applied to useful purpose in the arts.

Arsenic, when in the state of metal, is whitish colour, brittle, scaly in the fracture, very apt to tarnish, and at a comparatively mod degree of heat it passes entirely into vapour. arsenic usually sold is the white oxide; and th the metal is found very generally in some co nation or other, it is chiefly obtained from t works in Saxony at which cobalt is converted thc blue pigment called zaffre, or smalt. cobalt ores, as we already said, contain gene more arsenic than cobalt; and as arsenic is volatile, it is driven off by long continued he ovens, which have long horizontal flues or c neys, on the sides of which it is condensed, and afterwards be refined to any degree of pu Some of the oxides or salts of arsenic are use painting, the yellow sulphuret being known u the name orpiment, and the red, of realgar; *they are all* deadly poisons, the white oxide *the most deadly* of the mineral or corrosive p *and with the* exception, perhaps, of some

stupifying poisons, extracted from certain vegetables of warm climates, it is more destructive of life than any substance with which we are acquainted. Still it is used in the arts for giving a white colour to glass, and giving hardness and lustre to some compound metals. It is, however, exceedingly dangerous in all its forms, and requires to be managed with great caution. The ores of many other metals contain certain admixtures of arsenic which require to be discharged by roasting, and the fumes arising from such operations are equally disagreeable and dangerous.

Chromium is of no use as a metal, being merely a mass of particles; but the oxides, combined with a small portion of other metals, are of various shades of green, yellow, orange, and orange red, which are generally of great brilliancy. They are extensively used in painting, especially as greens and yellows, of which there are none others so bright. It is for this reason that the metal gets its name, which signifies that which colours, or produces colour. It is found combined with lead, and also with iron, from which latter it is usually extracted.

Molybdenum is a blackish metal, not obtainable in any considerable portion. Its ore which is found in several parts both of England and Scotland, is of a leaden grey colour, and metallic lustre. It can be employed for marking on paper, something in the same manner as that compound of about nine parts of carbon with one of iron, which is called plumbago or black lead, and so well known for its uses in writing and drawing and also for brightening the surfaces of cast-iron articles. Molybdenum, in the state of ore, is not at all equal to this substance; and the metal is obtained only in

small grains, which are of a grey colou
and not easily melted.

Tungsten is a metal of which but
known; and, like the last one, the little o
has been obtained is in small globules.
readily with most other metals, but not
phur; and it serves to give durability tc
the colours procured from vegetable dyes.

Columbium is also obtainable only
portions, and very brittle, though hard e
scratch glass. Hitherto it has been a
comparatively few uses.

Selenium is also a rare metal, of a
brown colour externally, but with the fi
the colour of lead, and of the shape of the
of glass; very thin portions of it are nea
parent, and the light through them is
It melts at not many degrees above th
point of water; but it softens so soon w
that it can be moulded with the fingers
out into threads. It is a much worse con
heat than any other metallic substance;
end of a bit of it may be held between tl
while the other end is melted. It has th
metallic character than any which we hav
enumerated; but still it belongs more to t
than to any other class of substances.

Uranium is but little known. It is fou
or three stony substances, in the state of
which can be used for colouring glass or th
of vessels, of a greenish, brownish, or
colour. In the metallic state it is dark g
hard. Osmium, Iridium, and Rhodium,
metals or metallic substances which
found in combination with platinum.

sess but little interest to the public. Rhodium forms an alloy with gold or with silver; and when in the metallic state it is very hard and not easily corroded, on which account the points of pens are sometimes made of it, fastened upon gold or some other metal; but in the present state of our knowledge of it it must be regarded as more curious than useful.

Cerium is another metallic substance found in combination with silica or flint; and when brought as nearly to a metallic state as possible, it is said to bear a considerable resemblance to those metals which form the bases of the alkalis and earths.

This is a mere list; but still when it is considered how numerous those metals are, and how disposed they are to enter into combination with each other, and with a vast number of other substances, we can readily see that those active principles which the Creator has imparted to matter, are not less numerous or much less interesting in the inorganic portion of the earth than they are in that which is organised. Further, as very many of the combinations and decompositions which take place in nature, or are brought about by art, among those substances, are attended with very strong demonstrations of heat and light, and capable of originating changes which may be extensively propagated through other matters, we can readily see that there are in the solid mass of the globe, powers amply sufficient for producing every form and combination of matter which we can perceive in it; and that to produce in it new metals, new earths, new-rocks, new lands, and every change of which we can imagine the globe to be susceptible, requires no more second effort of creative power

than it does to produce successive races of plants and animals, in the ordinary way of germination and generation. It is true that there is no organic structure in any mineral substance, no distinct parts fitted for separate uses, but that the whole of every mineral is perfectly homogeneous, unless when there is another mineral mixed with it.

In the mineral, taken in itself, we have therefore a far more limited field of observation than we have in the animal or even in the plant; and as we have reason to believe that the dawn of mineralisation, in the forming of an elementary crystal, must, like the rudimental development of a vegetable germ or animal embryo, be carried on when the atmospheric air and the solar beams are excluded, we cannot hope to arrive at the very beginning in this case, any more than we can do in the others. The tendency of the atmosphere and the action of the sun are always to decompose every mineral substance; and especially to evolve those parts of it which are useful for the nourishment and growth of vegetables; and hence the production of those minerals must take place in a situation from which those causes of decomposition are excluded. We shall, however, be enabled, afterwards, to throw a hasty glance on this part of the subject with more advantage; and so we shall now very briefly enumerate some of the principal earths.

EARTHS AND STONES.

THE EARTHS, which may be regarded as forming the most abundant and substantial ingredients of stone or rock, as these last form by far the largest proportion of the solid crusts of the

earth, as known to us, may perhaps be all regarded as first compounds of metals, with some other substance,—in many, if not in most of them, with hydrogen, or the base of water; and this circumstance alone shows us how very important the liquid part of our earth is, even to the original formation of the solid part; and that while the accumulated water, which rolls in waves to the gusts of the atmosphere, wears away the rock, water is also one of the elements, or at least it contains one of the elements, which enter into the formation of rocks. Indeed, the more intimately that we study nature, we find that there is the more close connexion between all the parts of it, including even those parts which, to our casual observation, appear the most dissimilar, nor does it seem that numerous as the kinds of productions appear to be, and varied as are the operations which take place among them, that a single one could bear to be removed without maiming and mutilating the system. It is true that we cannot number their days as we can number those of organic beings; and therefore we shall never be able to get the two histories exactly to correspond; yet, notwithstanding, we are enabled to see enough to make us feel that there is a connexion, and that one general law, though diversified without end, runs through the whole. As those earths are compounds of metals, with a single substance, probably, in each case in combination with the metal, and as we do not know the number of metals nor the number of substances which do or may combine with them in first combinations, we cannot possibly tell the number of earths; and therefore we must content ourselves with the enume-

ration of a few of the leading ones, or those which are most conspicuous and most abundant in that portion of the earth's crust which we can examine.

We have used the expression "crust," as applied to that very limited portion of the earth's mass to which we can extend our observation; and therefore it is necessary to caution the reader, who is not already acquainted with the subject, against any inference that he might draw from this word crust, as though it covered something different from itself. That the internal parts of the earth differ somewhat from the external, we have reason to believe; because when the weight of the whole mass is compared with its volume, we find that it is about four and a half times heavier than water; whereas the matters with which we are conversant in a mineral state on the surface, if we were to average them with great care, would not exceed three times the weight of water, if indeed they amounted to as much. Granite is one of our firmest rocks; and, judging from the position in which it occurs in the strata of the earth, there is every reason to believe that it is the one which has been formed at the greatest depth, and consequently by the most powerful action; for it is perfectly evident that the resistance against which a mass of rock, formed in the depths of the earth, is from the surface, must, in the average of cases, be in proportion to the quantity of matter over it; and as the power which upheaves the rock from this depth must be greater than the resistance (in order to overcome it) it must be greater in the case of a rock which comes from a great depth than from one formed in a situation comparatively shallow. Now, granite is, we believe, in no case three times as heavy as

water; and many other species of rock are still lighter. We must therefore suppose that there is an increase of density as the centre of the earth is approached; and we are very apt to suppose that metallic matter preponderates more there than it does nearer the surface, but of the specific kind of matter, the state in which it exists, or the compounds into which it may enter, we can by possibility know nothing, and therefore any conjecture respecting it would be an idle use of words.

The leading earths, or those which form the great bulk of all rocks, are the four following: silica, or the earth of flint; alumina, or the earth of clay; lime, or the earth formed of the metal calcium, but which generally exists in rocks, not as pure lime, but as combined with some acid; and magnesia, to which no other English name is given. Besides these, there are a vast number of others, but they generally exist in small quantity.

Silica exists in greater quantity than perhaps any other of these earths. It is the principal ingredient in very many rocks, and in some it is nearly pure. Popularly it is known by the name of flint earth, and the spar or nearly pure crystallised formations of it, get the general name of quartz; when pure, these are white or transparent, and the purest ones form rock crystal. The greater portion of the beds of sand which occur in larger or smaller accumulations both in the sea and on the land, are chiefly formed of silica: as this earth does not dissolve in water, or form a fine paste with water, so as to run off in a state of almost perfect liquidity like some of the others. Silica has the *remarkable* property of being converted *into glass, by an* admixture of various fluxing sub-

stances, such as potass and soda. It thus becomes an exceedingly useful article in the arts, as the basis of glass; and even when in this state it is proof against the action of all the acids, except the fluoric, which dissolves it readily, and therefore that acid cannot be kept in glass vessels. When silica is pure it takes the crystalline structure, and grains of sand are crystals of silica, though often coloured by oxides of iron and other matters. When it is combined with a certain portion of one of the more powerful alkalis, it always exhibits a fracture like glass. This is the form which it assumes in those nodules of flint which abound in chalk formations, or in those gravels out of which the chalk is understood to have been washed; and some are of opinion that those flints have been originally sponges, the alkali of which has attracted silica and converted it into that glassy structure which we call flint, and which, though very hard, is also very brittle. There are some springs in the water of which silica is held in solution, even in greater quantity than can well be accounted for by the alkali contained in those springs. It should seem, however, that in all cases where this earth is so held in solution, there is more proportion of alkali present. The Geyser fountain in Iceland is one of the most remarkable of these. It is a reciprocating fountain, throwing a great mass of water to the height of many feet in the air, with fierce ebullition, and the discharge of great clouds of steam and vapour. After those vapourised matters, which appear to be the immediate cause of the action, are discharged, the water again subsides into a pit; and as the portion which comes in contact with the earth becomes cooled by so doing,

it deposits the silica with which it is charged, in the form of an incrustation, of which there is a large basin surrounding the aperture of the fountain. There are several other of the hot springs in Iceland which deposit silica upon the adjoining rocks, or upon sticks, or any other hard substances which are placed in them; and some have this property so strongly as to cover a considerable portion of stick with silicious incrustation in a comparatively short period of time. There is no doubt that those fountains containing silica in the heated water which they discharge, are intimately connected with the general volcanic action which is so remarkable in Iceland, and in which the alkali necessary for this purpose is in all probability obtained from the beds of sea weed which have been so covered up by volcanic matter discharged over them as to retain the heat, notwithstanding the quantity of water that is over them. The probability of this is greatly strengthened by the fact, that the volcanos of Iceland have at different times discharged vast quantities of liquid glass, which has consolidated on cooling, but of which the surface is furrowed, as if the winds had acted upon it at the time when it was cooling.

Silicum, the base of silica, forming a little less than half of the pure earth, while oxygen forms the remainder, has not many of the properties of a metal; but as it is obtained in powder only, it is not easy to say to what extent it may have metallic properties. It is a dark coloured powder, and it is possible that it cannot be crystallised or otherwise formed into a uniform solid of considerable dimensions, without the presence of both oxygen and hydrogen. On the confines of our comparatively

limited knowledge of these elementary matters, there is, however, no small degree of uncertainty; because they resemble each other in so many particulars, that it is not easy to distinguish one of them from another. Silica may be obtained in a crystallised state from its solution either in fluoric acid or in potass in a liquid state, for if either of these is left at rest for a long time, crystals will begin to form; and it is not impossible that native rock crystal, as it is found in the earth, may be the product of similar solutions. We find remarkable instances of the glassy and crystalline structure of this earth in many of the agate pebbles. The external portion of the pebble has the glassy structure often more compact in the external parts than further into the interior; but generally having the external surface honeycombed, as if it had been compressed by solid matter of a rough consistency, when it was itself beginning to become solid. The interior, however, often consists of a mass of crystals, which are much more brittle than the external case; and these crystals never fill the entire cavity, and sometimes merely encrust the inner surface of it. They are often tinged of a bright purple colour, resembling that of the fumes of iodine; and as that substance is found in various marine productions in connection with soda, it is by no means improbable that the materials of those pebbles have been brought together in the sea; and the bases of them *may* have been sponges, only subjected to a different kind of operation from that by which flints have been produced.

Though silica is so very easily melted into glass, *when mixed* with alkalis or other fluxing substances, *it* cannot be melted by itself by any heat

short of that most intense artificial heat that is known, which is produced by burning oxygen and hydrogen in the same proportion in which they exist in water.

Alumina is the proper earth of clay; though it is obtained in greatest purity from its combination with sulphur, the most remarkable of which is common alum, a substance of most extensive use in the arts. One half, or nearly so, of native alum consists of water, and there is generally a great deal of potass. The sulphuric acid also is between three and four times as abundant as the alumina, and consequently the pure earth does not compose more than between a ninth and a tenth of the entire alum. The water may in great part be driven off by heat, without disturbing the other ingredients; and the substance thus obtained is neither crystallised nor transparent.

Alumina forms salts with most of the acids, and those salts are, generally speaking, soluble in water; but the earth may always be thrown down in the form of a powder, by the alkalis and by some of the other e rths. Some of those salts of alumina are exceedingly useful in the arts, for fixing colours upon stuff, and for a number of other purposes. The sulphate, or alum, is contained in great quantities in various clay formations, indeed in all which at the same time contain a sufficient quantity of sulphur; and it is remarkable that the portion of the formation nearest the surface is always the best. If the clay schistus (so called from its being composed of layers or plates,) is moistened with sea-water, it takes fire; but in the manufacture of alum it is usually burned artificially, in large heaps, the object being to prevent

so rapid a combustion as shall drive off the sulphur in a state of vapour. When properly burned the alum stone is soaked in water, by which means the alum is dissolved; and then when this is done the water containing the alum in solution is boiled down until so little is left that it crystallises on cooling, an intermediate operation being to allow the liquor to settle in separate vessels in order to deposit sulphate of lime, sulphate of iron, and earth in a free state, with which the sulphate of alumina, as prepared from the rock, is always more or less contaminated.

In nature, alumina performs a very important part. All the oriental gems of the greatest hardness, which according to their colour are called sapphire, rubies, or topazes, are formed almost entirely of this earth in a pure state, with little else than colouring matter, and a little addition of lime. Next to diamond these gems are by much the hardest and most compact of any known substances; and they are highly prized for this quality and for the brilliance of their lustre, and the beauty of their colours.

Alumina is in an eminent degree the plastic earth. It is very minutely divisible in water, and remains long suspended in that fluid. We cannot say that there is positively a chemical action between the particles of the alumina and those of the water, but there is a kind of surface attraction resembling that by which oxygen and nitrogen appear to be held together in common atmospheric air.

This disposition which alumina has to mingle *not to combine* with water, causes the clayey portion *of rocks* to be retained in thick beds whe

the other parts are removed; and those clay deposits are often of great use in the arts. Feltspar, which is one of the component parts of granite, and which besides forms many entire rocks, is one of those compounds which are most easily reduced in this way by the action of the weather. Upwards of six tenths of this mineral consist of silica, and about half the remainder of alumina; the chief other ingredient is potass, which exists in from twelve to fourteen parts in the hundred. The potass and the alumina dispose this rock to absorb water, and whether by alternate heating and cooling in the warm countries, or by the alternate freezing and thawing of the absorbed water in cold countries, it is in time reduced to powder. The silicious part does not dissolve in water, but when dry it is scattered by the wind; and the rains, while they wash the alumina down to the bottom of the broken mass in the form of compact and often water-proof sediment, wash away the silicious sand. It is in this way that many of those accumulations of pure sand which form the coasts of the land and banks in the sea, are produced, though they may also be produced by the decomposition of silicious rocks of any description. These are, on account of their larger size, in the individual portions, carried farther to seaward, than even that part of the alumina which is carried off by the water; although changes in the relative form and action of the land and the water, often make the deposits of sand and clay alternate and incorporate with each other. All the pipe clays, and also the porcelain clays, or *Kaolins* as they are sometimes called from their Chinese name, are of *this description*; though even the softest and whitest

of them rarely contain more than fifty per cent. of pure alumina, the rest being silex or some other earth, and sometimes in part metallic oxides and salts. When metals are present, even in very moderate quantity, they colour the clays, which then become unfit for pure white porcelain; but some of those which are coloured grey by oxide of iron make pottery of great strength.

In all their states those clays, or compounds of aluminous earth reduced to a state of powder by the action of water, are very useful to mankind. Soils which contain them, if mixed with a proper quantity of decayed vegetable or other organic matter, support a stronger vegetation than any other soils; but when there is too much alumina in the soil, in proportion to the other matters which would keep it open, it is rendered unprofitable, and in some states of the weather unhealthy. In the dry weather it binds, and opens into large fissures, or cracks into fragments; and in wet weather the surface of it becomes a puddle to a very considerable depth, so that it cannot be walked upon without difficulty, or in many cases without danger. In the former case the roots of vegetables are constricted so that they have not room to work; and in the second those which take but a slender hold in the ground are apt to be thrown out, and so to be killed by the frosts. If the climate is rainy, and the surface of the ground flat, those clays retain the moisture, so that it can escape from the surface by evaporation only; and as this evaporation keeps up a great ascending and descending of moisture in the lower strata of the atmosphere, such places are unhealthy, as compared with those in which, from a proper admixture of other ingre-

dients less tenacious than clay, are more porous and allow that superabundant moisture which is not carried off by the water-courses, to penetrate into the ground. There is another disadvantage in those beds of clay, when they are deep and very plastic and retentive in their nature: there is never any water in them, either to supply springs, or to be got by digging wells, unless the well is sunk fairly through the clay, to some stratum of a different kind which lies under it. This is well exemplified in what is called the London clay in the valley of Thames; though other minor formations with which it is interspersed vary its character in different places. In some situations it is more than two hundred feet in depth, and quite pure; and in such cases there is not a drop of water to be obtained by digging or boring unless the clay is fairly perforated; and therefore, except the small portion of water which accumulates in the surface materials above the clay, there is none to be had in the dry season, while in the wet season the surface is miry and disagreeable. But when a clay formation such as this occupies a hollow, as it generally does, and crops out in more porous strata upon the higher grounds, it becomes a sort of reservoir which human ingenuity has converted to some useful purposes. The whole covering of clay, which prevents the surface water from descending, equally prevents the bottom water which finds its way by the more porous strata below the clay from getting up; and thus the gravel or other loose formation, if there happens to be one under the clay, becomes an ample store of water, generally of excellent quality and much more easily accessible than one would suppose it to

be considering the depth at which it lies. The inlets of the water in the porous strata of the adjoining slopes are, as it were, the fountain heads; and as water will rise to the level of its fountain head by hydrostatical pressure alone, it is only necessary to bore through the clay, even upon one of those little eminences which usually diversify its surface, and the water will rise to the surface, or even above it. There are two reasons for this: the weight of clay surrounding the bore is much greater than that of the water in the bore itself; and if the bore is of even moderate dimensions the water can escape, from the pressure of the superincumbent clay upon the stratum which contains it, much more easily by this bore than backwards through the stratum to the fountain head. Hence in the clay districts about London, it is common to bore through a great depth, and get a very copious supply of excellent water from the sand or chalk below; and this at much less cost than one would be apt to suppose.

The use of clay in forming mortar and in supplying the materials of bricks and the various kinds of pottery, need hardly be pointed out, as every one is familiar with it. In some parts of the country very substantial houses are constructed of stone kneaded in clay and applied to a frame-work of timber; and in many parts of England, and of most countries, bricks form the staple building material, and in some respects they have a decided advantage over stone. It so happens, too, that those districts in which bricks can be most advantageously made, there is commonly very little native stone to be met with. Even the strongest clays used in brick-making contain a large admix-

ture of silicious matter in the form of sand, and also iron, and not unfrequently lime. If those ingredients are not naturally in the requisite proportions, the manufacturer can temper them as he has a mind; and it is customary to add a quantity of lime, which gives the brick a whiter appearance, and also assists in the process of burning.

In bricks, and also in every kind of potters' ware, alumina, or earth of clay, is the stubborn part upon which the heat of the kiln or furnace does not act; and the silex, aided by the lime, and generally also by some other of the components parts, is partially converted into glass, which is intimately distributed among the particles of the clay, and gives a firm structure to the whole mass. The alumina, which otherwise would be brittle when dry, is cemented by the meltable or vitrifiable portion; and this portion, which, if converted into glass in bulk, would be brittle, is rendered tough because the particles of alumina prevent a fracture from being propagated through it, as would otherwise be done.

It is very probable that very many rocks are cemented together in this manner; but when such rocks contain too large a portion of clay, and have not undergone the action of a strong heat, they make not very durable building stones, as the water is very apt to soak into them. Clay formations, when consolidated into stone of any kind, are almost invariably formed in plates or layers, having what is called a schistose structure. These beds are often exceedingly thin in their individual formations; but they frequently adhere much more firmly at some parts of their union than at others; and in consequence of this they can generally be

quarried from the rock of various thicknesses, according to the purposes for which they may be wanted. Where the leaves composing those clay schists are very thin, it is generally understood that the rock has been formed by a slow deposit from water carried on for a number of years. The separations of one from another are also supposed to mark the pauses during which no deposit was taking place, and which probably were seasonal, in the quietude of the rivers between the floods; and we may naturally suppose that where the beds—which is the name usually given to those thicker masses which have little cohesion—were marked at seasons of a peculiar character. Those schistose beds vary in their quantities of clay, and also in the other ingredients which they contain; but they all appear to have been originally formed gradually, not by any of those sudden out-breakings of the more powerful causes of which there are so evident traces in many parts of our globe, but in the ordinary course of events, how much soever that course may have differed from the one which we at present witness, but of the effects of which in the formation of anything so durable as a stratum of rock we can form but very imperfect notions. It is probable, however, that they were all deposited on a level, or at least quietly on the bottom of the waters, whatever the form of that bottom may have happened to be.

At present, however, their position is very different from this; for they are bent, and twisted, and broken, so that they stand at all imaginable angles to the horizon, and lead us to suppose that *after their* formation, they have been subjected to *something* more energetic than those quiet agencies,

by the operation of which they appear to have been formed by the joint action of the air and the water, without the assistance of any of those more powerful causes which agitate the earth, and in all probability occasion the elevation of continents, and the depression of the beds or basins of seas. Our space will not admit, however, of our entering farther into the details of this portion of the mineral kingdom.

Lime is the next earth which we shall notice; and it also is very abundant and very generally distributed. In its substance lime is the oxide of calcium, which last is a metal, the base of lime, but not of any other known substance; and so great is its tendency to unite with oxygen, that it burns, or passes into the oxide in a state of dry lime, when exposed to a very moderate degree of heat. If placed in water, it combines rapidly with the oxygen of the water, and passes into the state of pure lime diffused through the water invisibly, while hydrogen is given out. In this pure state, lime is very caustic, and highly injurious to animals and to plants. When freely exposed to the air, however, it remains in this state for only a very short time, in consequence of the tendency which it has to absorb water. When it is saturated with water, it becomes what is called slaked lime, which is a hydrate; and then it is not so caustic. Lime also combines readily with chlorine, in which state it is a powder, readily soluble in water; and the solution of it in water is the bleaching liquid to which we formerly alluded, and it is also very valuable for removing infectious vapours, and thus purifying ships and other confined places. Lime is the earth which chiefly forms the hard parts of animals—the

bones, the crusts, and shells. In the bone it is in the state of phosphate, in the pure shell it is a carbonate, or nearly the same in substance as common limestone or marble, and in the crust it is partly the one and partly the other; but in all these structures it is cemented together by a tissue of animal matter, and not in the form which we meet with in minerals. Lime, whether quick or slaked, readily mixes with moistened vegetable matter, part of the compound becoming soluble in water; and it is as probable that it is by effecting some decomposition of this kind, that lime is useful as a manure; and it is useful in this way, whether obtained directly from limestone, or from beds of broken shells in the sea, or shell marle which appears to consist of the same substance, more completely disintegrated. Chalk, however, and completely decomposed marle, and also lime which has been thoroughly saturated with water for a long time, so as to have entirely lost its caustic taste, do not decompose vegetable matter. In these last states, however, it is still useful in loosening the tenacity of soils which are too retentive. Of course, when lime in an active state is applied to soils already abounding in calcareous matter, and deficient in animal and vegetable matter, it both weakens the texture of the soil, and lessens its productive power; so that, after all, lime must be regarded as partaking of the character of a medicine or corrective to the soil, rather than of a direct nourishment to it; and therefore it requires to be used with caution. The use of lime as a mortar is well known; but there have been several improvements in the application of it of late years, chiefly with a view of making it set or consolidate sooner

than it does naturally. This is in great part accomplished by having the lime hot, and the sand and water mixed with it immediately previous to its application.

The most prevailing forms of lime, as a mineral native in the earth, are those of the carbonate and the sulphate. The carbonate forms the common limestone and marbles, but it is variously mixed with other earths, and also with the oxides of metals. When the carbonate is exposed to heat, the carbonic acid, together with the water which held the lime in a crystallised state, is driven off; and the remainder, which is considerably diminished in weight, becomes quick-lime; and if this quick-lime is sprinkled with water, it absorbs the water with a considerable degree of heat, and becomes slaked lime; but in this state it does not set or consolidate, unless sand (and the purer the sand is the better) be mixed with it.

Mortars which are to be used for works constantly or generally under water, have the lime consolidated to a hydrate only; and therefore they are generally combined with some other ingredients, the whole forming what are called building cements. Those cements, besides the lime, contain mixtures of the powders of silica and alumina, with oxide of iron, and sometimes a little of that of other metals. Decomposed and calcined volcanic rocks, also, answer very nearly the same purpose, for they contain pretty nearly the same ingredients intimately blended with each other. If the mortar is used in buildings exposed to the air, it gradually attracts carbonic acid, and becomes a carbonate, *which in old buildings* that have been constructed *with good mortar* is often harder than the stone

itself. Common plaster stone—which, when pure, is alabaster, and which occurs in large beds in many parts of the world—is sulphate of lime; and as the sulphuric acid has a strong attraction for lime, this salt is not decomposed, but merely has its water of crystallisation driven off when it is calcined by heat. It is then ground, and made into a paste with water, which paste very speedily sets; and therefore it is much used for making moulds and moulded figures, and is in fact a very manageable and rather a useful substance.

Though when lime is burned in the free air with moderate heat, it passes into quick-lime, yet if the heat is too great, and the access to the open air interrupted, the lime may be melted into a sort of glass, chiefly by the vitrification of the silica which is mixed with it. If sufficient heat is applied, with the atmosphere excluded, and under a pressure which resists the escape of the carbonic acid in the state of gas, any carbonate of lime, such as powdered marble, chalk, or shells, may be reconverted into granular marble in a solid state, or even into crystals. Indeed the effect of sufficient confinement and pressure upon heated substances generally makes the result very different from what it would be if they were exposed to the same degree of heat in the open air; and therefore we can draw no positive conclusion with regard to the effect of heat upon the substance of rocks while burried deep in the earth, from what we witness on the surface, or from what we observe in the action of those volcanoes which open to the air, and there discharge their contents. In these last there is, as we might *naturally* suppose, something intermediate between *what takes* place in our furnaces, and what occurs

within the solid mass of the earth. The upper part of the volcano acts like an open fire, producing ashes or cinders, according to the nature of the substances acted upon; while lower down, and under the pressure of the column of liquid matter in the chimney of the volcano, the metals and stones are melted together into the substance to which we give the general name of lava, and which may be taken as the type of a class of rocks which we shall name afterwards. There appears, however, to be some decomposition even at the greatest depth from which the discharges of these volcanoes come; for the more volatile ingredients even, as sulphur and a few others, arise in fumes, and are condensed upon the sides of the chimney; while there are some volcanic grounds which constantly send out the vapour of sulphur and other products, in a state in which they readily, and even spontaneously, take fire. In the rocks which come from a greater depth, we do not find this blending of all the parts into one common mass, as we do in the volcanic products, though they are often more firmly united together than the parts of an apparently uniform piece of the latter; but in them we very often find that the metals have separated, and taken hold of a large portion of the oxygen, sulphur, and other active substances, forming with these the different ores in which metals, which are dug from the rock, or the adventitious matter in the vein or fracture of the rock, are contained.

These few considerations will prepare us for a brief glance at the general structure of that part of the earth to which we have partial access; but before we take that very fleeting glance, we must mention one or *two of the other* earths, which, as well as

the three now mentioned, enter pretty largely
the composition of those minerals which belo
the class of stones, in the popular meaning o
word, and not to metals, their ores, or their o

Magnesia is the next in abundance; and it i
oxide of a peculiar metallic base, to which the
of magnesium has been given. This metallic
which is very difficult to be obtained in a sep
state, resembles the base of lime in its ki
action, but it is not nearly so energetic. It req
a pretty strong heat to convert it into magne
the air, and the conversion in the water go
much more slowly than that of lime. Heat
does not so quickly deprive carbonate of li
its carbonic acid as it does carbonate of magn
and when magnesia is calcined it does not r
moisture from the atmosphere nearly so soon;
those circumstances show that the attracti
magnesia, both for carbonic acid and for wat
much weaker than that of lime. Many limes
contain a considerable portion of magnesia, and
may be so burned as to decompose the mag
and leave the lime in the state of a carbonate
is generally supposed that magnesian earth
useful ingredients in soils, because districts v
the soil contains them are remarkable f
kindly, if not for a vigourous vegetation.
is the same, we may add, with those rocks v
contain limestone, and, generally speaking,
with those which contain decomposed vol
products; but whether those earths have any
action upon the plant, or influence it merely thr
the medium of the mould, or decomposed or
matter, has not been satisfactorily determined.
are indeed so ignorant with regard to the fo

which plants receive their food, and the process of vegetable assimilation, by which they convert it into their own peculiar structures, that we are unable to form any theory as to what in a soil must or must not increase the action of vegetables, but must rely entirely upon experiment.

Several of the salts of magnesia are soluble in water; and they accordingly abound both in land springs and in the sea. Sulphate of magnesia is the common Epsom salts of the shops; and it may be formed either from the water of such springs as are impregnated with it, or from sea water. Magnesia, or its carbonate, is often used for correcting acidity in the stomach, from the readiness with which it combines with most acids; but if taken for too great a length of time, it is apt to form insoluble compounds which are injurious; it is supposed also to be useful in helping to dissolve one form of stone, namely, that which is chiefly composed of uric acid; but there is, at the same time, some danger of its doing equal mischief on the other hand, by forming stones composed in a great part of phosphates of magnesia.

The mineral substances which contain a large admixture of magnesia, have generally a soft feel, and many of them are flexible, and some even capable of being spun into threads and woven into cloth. The general name for these is asbestos, which usually contains nearly double the quantity of silex that it does of magnesia, and also some other ingredients. One form of it is called amianthus; it is in long flexible fibres, of a silky texture, and the ancients made of it what was called their indestructible cloth. It is not, however, absolutely *indestructible*, even by the heat of common fires;

or though it resists powerfully, and comes out of the fire cleansed from all extraneous matters, it is always a little wasted. Common asbestos is flexible, but in an inferior degree to amianthus, and cannot be spun into threads, though the fibres of it are all ranged in the same direction. When the fibres are interlaced crossways with each other, this substance, which is then tough and flexible, is called mountain paper, when thin, and mountain leather, when thick. Other forms are called mountain cork and mountain wood, from fancied resemblances to those substances; but they are all substantially the same, only differing a little in their proportions.

The most abundant mineral, and that which contains the larger proportion of magnesia, is that which is called serpentine. It is greasy to the feel, and generally of a green colour; but some of it, though much softer than marble and more easily cut, admits of a pretty high polish.

The remaining earths do not enter so largely into the composition of the mineral part of the globe, and therefore we shall notice only a few of the more remarkable ones.

Barita is an earth which is obtained in conside able quantity, generally in the form of a sulpha which is very heavy, being from four to four an half times heavier than water, according to purity. On this account it is called heavy s The pure earth is an oxide of a metal to which name of barium has been given; but as it oxi rapidly at the common temperature of the a never exists in a pure state; and indeed the stance is itself not obtained except in the fo a sulphate. The sulphate of barita is use white pigment in water colour painting, v

various purposes in the arts. Strontia bears a considerable resemblance to barita in many respects, but the spar or native crystals of it are not so heavy, and the salts have not the same poisonous qualities. Most of the other earths exist in very small quantities, are locally distributed, not used for many purposes in the arts, and they do not appear to perform any very important function in the economy of the globe; we shall therefore pass them over, and proceed to a very brief notice of

ROCKS, AND THEIR ARRANGEMENT.

The science which treats of this department of nature, and to which great attention has been paid of late years, is called geology, which literally means the tale which the earth has to tell of its own history; and when we consider that from the surface of the earth to the centre is nearly four thousand miles, that the points at which man has penetrated to the depth of one mile are exceedingly few, and that the portions where the earth has been penetrated at all beyond the mere surface soil which is scratched by the plough, form so small a fraction of the entire surface, as hardly to admit of statement in numbers; we must readily admit that this tale of the earth must be a very imperfect one—a mere fragment as it were, or different fragments, the connections between which it is often difficult to make out.

But still, it is equally easy to see that this is a branch of the knowledge of nature which has particular attractions for the human mind. The earth is our dwelling-place; it supplies the substance of our bodies both in their original growth and in their subsequent repair; and it is the common

receptacle of our mortal remains, until the years of its duration as the abode of human beings shall be numbered, and the decree shall pass, and the judgment be appointed upon it and upon its inhabitants. There is also in the human mind a strong principle of the love of mere antiquity, and consequently a desire to know every thing which is ancient; and this desire, kept, as all desires ought to be, within the bounds of moderation, is a commendable desire. It is from the past that we learn all our wisdom; and as hope impels our minds strongly towards the future, we require some ardent desire of the past to prevent us from breaking away from the maxims of experience, and chasing to our injury or our ruin those phantoms of delusive hope, which always fly the faster the more eagerly that we give them chase.

Of all that can come within our close observation, the earth is the elder born; for though we have no means whatever of comparing the ages of suns and planets, it is perfectly evident that as the earth supports, and actually furnishes, every thing which moves, or grows, or lives, upon its surface, or within its atmosphere, the supporting earth must have been pre-existent even to the most ancient of those inhabitants of which it supplies the materials.

There is also an analogy which draws our attention very strongly to the contemplation of this subject. In all parts of creation where we can see one complete cycle or period of change, in any one created being or thing of material creation, whatsoever it may be, there is a protecting care implanted in its very nature, which enables it to repair all injuries, and overcome all difficulties which may come in its way; and if this be true of all minor

things upon the earth, it must also be true of the earth itself. No doubt the earth is placed so widely remote from every other celestial body, and the laws of those bodies are so beautifully established, that there can be no collision between any two of them, and no permanent injury done to any one by the rest. It has sometimes been said that the most serious consequences would result if a comet were to cross the path of the earth; but a comet is so very filmy and unsubstantial, that it might be very possible for the earth to pass through a comet, without any of the earth's inhabitants being aware of the fact.

It is not, therefore, against external injury from the heavenly bodies that the earth requires to be fortified, it is against the working of its own peculiar system,—chiefly the renovation of its own surface. As the surface of the earth, considered as mineral, and also as organic matter in a state of decomposition, is passive, and as there are many active agents continually at work in producing changes upon it, the balance of the system requires that the mass of the earth should, in some way or other have implanted in it a power of renovating this continually wearing surface. The lightest substance composing the solid earth, is far heavier than atmospheric air; and therefore there is a constant tendency in every piece of matter which is elevated above the mean surface to sink down to the level of that surface. The economy of the surface requires, that winds should blow, rains beat, rivers roll, and the billows of stormy oceans assail the coasts of the land. In all those operations, which are continually going on, there is a *disintegration of* the solid parts of the earth; and

though different kinds of solids resist with different degrees of force and for different periods of time, yet there is an effect upon all. The summit of the lofty mountain may be composed of the hardest stone; but its very elevation accumulates the power of disintegration upon it, in the alternate freezing and thawing of water; and therefore the upper slopes of high mountains, and the bottoms of those precipices which often form parts of their sides, are scattered with ruins, which tell as clearly that the mountain is in a state of decay, and, must some time or other be levelled to its base, as the common symptoms of age tell of the certainty of death in the human body. The individual mountain can no more return than the individual man; and therefore it becomes necessary, that the earth should be invested with the power of producing another; or else the earth would be an anomaly in the creation, left without the protection of that Providence which watches over and preserves everything, and which works not by miracles but by means, the knowledge of which, as far as observation and sound reasoning can go, is equally the province and the duty of man.

Did our limits permit, it would be easy to point out how all things which are in an inorganic state, and which are exposed to the surface action on the earth, must be disintegrated, in the same manner as we have instanced in the mountain; and it must be also evident, that the general receptacle, or perhaps we ought rather to say the final receptacle for all this disintegrated matter must be the lowest parts of the solid portion of the earth, which are evidently the beds or basins which contain the ocean waters. No doubt there are many pauses

before the same matter which once formed a towering rock or the lofty peak of an inland mountain, shall become sand on the sea-shore, or gravel and mud quiescent at the bottom. It will naturally take up its first repose, where the water first stagnates a sufficient length of time for letting fall a sediment; and there are many such places from which it may not be wholly dislodged by any future action of the weather; but until the level of the sea is actually arrived at, and the action of waves and currents throw back the spoil of the land, and form a bank, there must be some escape to lower ground, by every descent of heavy rain, which washes the surface into the water course, and at the same time swells the water so as to enable it to carry off the spoil. This is a part of the process which any one may see in any country; and more especially in a country where the surface is very much diversified by abrupt mountain and deep valley; and where, as is almost invariably the case in such places, the winds are constantly stirring and rain storms are frequent and violent. In the north-east part of Scotland, from Aberdeen to the narrow portion of the Moray Firth, the physical circumstances of the country render it peculiarly exposed to violent autumnal rains. A large portion of it near the sea is flat, sandy in many places, and altogether dry and warm for the latitude. Inland, the loftiest summits of the Grampians reach near the line of continual frost even in midsummer; and these mountains extend like a giant wall along the whole western side of the district. In early autumn the cold of winter returns, Lapland snow falls upon the mountains there, and the air is condensed, at the same time that the lowland part of the district of

Scotland just alluded to is warm and dry, and the air over it expanded. The cold air presses in from the north-east; but as it arrives over the warm country it expands and is a drying wind, so that it passes into the interior loaded with humidity. When it arrives near the mountains, it is reduced to their temperature; and the momentum which it receives in sweeping along tends also farther to condense it. From the joint operations of these causes the condensation and cooling are both rapid; and as these destroy the capacity of the air for humidity, in proportion to their own action, it precipitates the rain in torrents upon the slopes of the mountains; and all the mountain streams assume very speedily the magnitude of rivers; while the larger ones further down the country, whose courses are more level, become swollen, and inundate their banks, and frequently not only carry away the crops from the fields, level the houses, and put the people in great peril, but sweep the land itself onward to the ocean; or so cover it with those ruins of the higher ground which they have brought down, that it is useless for every purpose of cultivation.

Occasionally those violent rains break in perfect floods, upon the tops of the secondary mountains, which are often composed of loose gravel, covered with but a scanty crop of vegetation; and if the top of the secondary elevation happens to run, as it often does, upon nearly a level toward the base the more lofty one, the quantity of water which, in a very short time accumulates upon the level is sufficient to divide the surface on the brow and open a passage into the gravel; and then down comes the whole hill side in mass; and we have

seen instances in the district alluded to, where trees of some size were sanded up to the branches, and the more lowly shrubs completely buried at the base of the hill, while farther down toward the valley the top of the cottages, and here and there on the outskirts, the tops of the ripe corn appeared through the ruin.

Such catastrophes are not of daily, or upon a great scale even of yearly occurrence, in our island; but they do happen, and that at such short intervals, that they are never forgotten. Now the surface powers work tamely in our mild climate compared with what they do in many other regions, both in the polar countries where the seasonal rains are heavy beyond anything that we can well understand, and in some of the polar countries where the spring freshes produced by the sudden melting of the snow, bring fields and forests and great stones in one tumbling ruin toward the sea. Nor is the sea itself less active in this work of destruction. In many parts of the east coast of England, the sea is rapidly encroaching ; and in exemplification of this we cannot do better than quote the following passage from Lyell's very interesting elucidation of the principles of Geology. "The sea," says Mr. Lyell," undermines the high cliffs a few miles north of Lowestoff, near Corton ; as also two miles south of the same town, at Pakefield, a village which has been in part swept away during the present century: from thence to Dunwich the destruction is constant. At the distance of two hundred and fifty yards from the wasting cliff at Pakefield, the sea is sixteen feet deep at low water, and *in the roadstead* beyond, twenty four feet. Of *the gradual destruction* of Dunwich, once the most

considerable sea-port on this coast, we may have authentic records. Gardner, in his history of that borough, published in 1754, shows, by reference to the documents beginning with Doomsday Book, that the cliffs at Dunwich, Southwold Eastern, and Pakefield, have been always subject to wear away. At Dunwich, in particular, two tracts of land which had been taxed in the eleventh century, in the time of King Edward the Confessor, are mentioned, in the Conqueror's survey, made but a few years afterwards, as having been devoured by the sea. The losses at a subsequent period of a monastery—at another of several churches—afterwards of the old port—then of four hundred houses at once—of the church of St. Leonard, the high road, town-hall, gaol and many other buildings, are mentioned, with the dates when they perished. It is stated that, in the sixteenth century, not one quarter of the town was left standing; yet the inhabitants retreating inland, the name was preserved, as has been the case with many other ports when their ancient site has been blotted out. There is however, a church of considerable antiquity, still standing, the last of twelve mentioned in some records. In 1740, the laying open of the church-yard of St. Nicholas and St. Francis, in the sea cliffs, is well described by Gardner, with the coffins and skeletons exposed to view,—some lying on the beach, and rocked

In cradle of the rude imperious surge.

"Of these cemeteries, no remains can now be seen. Ray also says, that ancient writers make mention of a wood a mile and a half to the eastward of Dunwich, the site of which must at present be *so far within* the sea. This city, once so flourish-

ing and populous, is now a small village with about twenty houses and one hundred inhabitants." Vol. 1. p. 273.

Some of the saline matters which are contained in these disintegrated rocks and other formations, are soluble in water, and as such they may be generally diffused through the ocean waters, and enter into the economy of its growing and living productions. But by far the greater part is not soluble in water; and therefore as it is taken from one place it must be deposited at another. The transfer of earths and integrated stones by the currents of water is a more easy matter than we would be led to suppose, for few of them are much more than three times the weight of their bulk of water, and many of them are not so much. The water always supports or neutralises a weight equal to its own, of every substance which is contained in it; as, for instance, a vessel floats, because the whole weight of the vessel is exactly equal to that of as much water as the portion of the hull which is immersed. Upon this principle it must follow, that in moving any matter which is submerged along with the current that matter will, supposing it three times the weight of water, be moved by a third less force than could move it upon the land. We are not very intimately acquainted with the ground currents of the sea, or indeed with the surface ones; and it is highly probable that they are continually changing, from the alterations of the forms of shores and banks. We know, however, that minutely divided matter can be carried to a very great distance, of which we have abundant examples in *those* banks which are evidently formed *by depositions* from the water, and not by means of *any more violent* action of the earth below. The

banks which lie in the eddy between the northward and southward tides, between the east coast of England and the opposite part of the continent, furnish an example of this; and there is little doubt that the debris or disintegrated matter washed down by the rivers on both sides have contributed to those extensive accumulations of rubbish. The great fishing banks which lie off the island of Newfoundland, at a considerable distance from any part of the main land of America, and far from the mouth of the Mississippi, which discharges a vast quantity of disintegrated matter into the sea, and which lies in an eddy, as well as the banks in our seas, is another and more extensive example; and if we were careful to examine the map we should find these deposits in the sea itself, very generally distributed over all those parts of its bed where there are eddies of the currents.

If we take the means of disintegration to which we have alluded, bearing in mind how constantly they are at work, and then take the means of deposition and accumulating, by the sea and by fresh water, we cannot fail to perceive that there are ample means for the formation of new rocks, or at all events for the collecting of the materials of them. If we suppose that the accumulation is gradually made during a long period of time, we may expect to find the resulting rock composed of thin strata, more or less united in their surfaces, according as the time between the successive deposits had been shorter or longer; but if the matters are brought together more speedily, and consequently with greater violence, we may expect that the strata or layers will be found of greater thickness; and if the matters are uniform, and no

change is interposed between the deposits, we may easily imagine a very great thickness of rock accumulated in this way, without any division into strata, but in the form of a liver-stone, that is a stone in which no bed is traceable in one direction more than other. Many of the sandstones, or freestones as they are called, have this structure; and where they have it, there are usually very soft when deep in the quarry, and moist, though exposure to the air often consolidates them into durable building-stone. We find great depths of sand, in nearly a pure state, accumulated in this way by rivers, and especially by the sea; and we also find it formed by eddies of the wind into hills of considerable elevation, as may be seen at several points on the east coast of Britain, and also on the continent opposite. Such accumulations of sand, mixed with cementing matters, such as a small portion of alumina, or lime, which, from their more minute division, can be carried more easily and further by water in motion than the sand can be, may be supposed, under sufficient pressure, to acquire the consistency which those freestones have in the quarry, without any other action.

We thus see that there are abundant means for the formation of new rocks, the general character of which is to be stratified or deposited in beds over each other, the materials of those beds depending of course upon those matters which were disintegrated. They may be any sort of earthy matter which can be mechanically divided without being decomposed; and their thicknesses and alternations with each other depend upon those former strata out of whose ruins they have been constructed; and therefore we can neither tell whence they came

or by what channel they were brought, unl
those cases where we see the disintegratio
the new accumulation going on.

We may suppose, however, that except in
as affected by the motion of the water, which
throw them into ridges and furrows, or hil
pits on the surface, those materials would ob
law of gravitation, and range themselves as
level as the form of the bottom on which the
deposited would allow.

But when we take into consideration the re
ing actions which, in addition to those now
tioned, are necessary to give to the eartl
renovating power of its surface which we
all the active parts of creation, we must not
to find those strata always, or even general
the positions in which they were originally
sited. We have said, and the truth mu
apparent to every one, that the tendency
whole of those surface agencies which operate
the materials of the earth, whether in disunit
accumulating, is to bring all things to the
level of the spheroid of rotation, because tl
nothing in it which can raise them again t
considerable elevation. The period when thi
level would be arrived at is beyond our estin
the more especially that we in general obser
results of its progress, counteracted by, and
up with, the effects of other causes; but in
sandy deserts of Northern Africa and other
where complete disintegration of the stra
taken place, down to a level where there is n
to collect clouds, and fill a water-course to
off the rubbish, we behold thousands of
miles lying profitless and barren under the

ling ruins of their old rocks. In the dry countries too, near the Red Sea, and in many other places, where the hill tops are so much disintegrated that they drink up like a sand bed the few showers that fall, we find an earlier stage of the same progress of ruin, but one which, though it still furnishes subsistence for a few scattered Bedouins and their flocks, still points as certainly to the final desolation of this disintegrating process as the most thirsty spot in Sahara.

These examples, and there are many more in other parts of the world, are sufficient to teach us, that in order to render the earth wholly unfit for animal and for vegetable life and growth, by means of its own surface action, it is not necessary that the whole of the solid matter should be blended with the sea, or even reduced exactly to the level of its surface.

Those surface actions are the means by which the mineral kingdom in the system of nature is made subservient to the purposes of growth and life; but while they minister for good to the plant and the animal in its season or for its period, their effects upon the mineral kingdom are all destructive, and tend to ruin. We must not suppose, that in this, there is any want of that goodness which is traceable throughout those parts of the system, which, having shorter periods between their commencement and their close than continents and islands have, we can observe throughout the whole period. The support of every thing is a species of destruction. The plant (though we know not exactly the manner) drains the soil; and in time, renders it unfit for the same kind of plant—fit only, indeed, *for an inferior* vegetation, for in many parts of our

own country, heath, and moss, and lichen, have taken complete possession of many extensive tracts, which bear the clearest evidence that at no very remote period they have been clothed with timber of stately growth. The animal again consumes the plant; and one animal consumes another, until we at last come to man, who is the most general consumer—the grand destroyer of the whole as it were. In all these cases, however, there is an antagonist power, there is an energy of reproduction, and a power of endurance in the organised being, beautifully proportioned to the burden which is laid upon it in the maintenance of the system, but always so much greater than the means of destruction of the same being, as to maintain it in its place.

The earth is the universal table at which all are fed; and therefore the analogy demands that there should be in the earth an antagonist power, fully capable of counteracting that disintegration, decay, and ruin of the surface, which are the tendencies, and without such an antagonist power would sooner or later be the results, of that very change of season, and that expansion of growth and enjoyment of life which we so much admire.

Nor is such a power wanting. Volcanoes and earthquakes show us upon a small scale, what the energies which generally slumber in the earth till their appointed time—of which we of course can have no knowledge, arrives—can accomplish. In the earthquake, we have cities levelled in a moment, the earth cleft for leagues, to a depth which defies the plumbline, vast rocks moved to and fro as if they were grains of sand, hills uprooted, lakes turned into dry plains, dry plains into the beds of lakes, and the whole face of nature so changed

that its oldest inhabitant could not perceive its identity. In the volcano again, we find miles of country covered fathoms deep with molten stone; whole provinces covered with ashes, islands shot up amid volumed smokes and burning lightnings, from the very depths of the ocean; and that against the pressure of the superincumbent water, and, as we may suppose, a resistance of old ocean's bed, more formidable in comparison with any resistance which we can witness upon earth, than if man were to attempt cleaving a mountain in twain with the blow of his hand.

In those cases, as in every case in which action produces an effect, the active force must be more powerful than the resistance is strong; and while we cannot help wondering, and all but trembling, at that which is done, we cannot help feeling that the doer is still more terrifically powerful; and yet, in the cases to which we have alluded, this doer is a simple second cause, operating under the guidance of Almighty wisdom and goodness, operating upon a little globe, which is amid the glories of the universe, not greater than a mote in a sun-beam, and operating on a few spots, which are but as mere points compared with the whole surface of the earth. Now, if so limited an action of so secondary an energy can produce effects which to us seem so fearfully sublime, what shall we, what can we think of Him, in whose sight such an energy, though multiplied up to the highest number which the human tongue can pronounce, would still be but as nothing!

In the present state of the world, earthquakes and volcanic *fires*, especially the latter, appear to *be far less* numerous than they have been at some

former period; for though we must not r every accumulation of partially melted stone ' we meet with in countries whose inhabitant known to have kindled signal fires of wood the mountain tops; yet there are distinct tra volcanoes in very many parts of the world, and are few countries in which volcanic product not to be found in great abundance; and ' ever they are found, they present characters render it impossible for us to mistake them.

But even in the utmost energy of this vo action, we have no evidence of any country o siderable extent being formed by volcanic m and besides, though the volcanic matter h many instances formed islands, and in others siderable portions of rock, it always bears evi of being a local product, as compared with the mass of the globe. We must therefore have rec to something more powerful, more central therefore more capable of producing those g renovations of the earth, which appear to be tial to its maintenance in a state fitted for ar and vegetables.

And when we examine the strata of the lofty mountains, and distinguish the parts of which do not appear to have been formed l posits, or ejected by volcanic fires acting at rate depths, we can at least guess at the fac far more powerful and more general action— probability of heat—than we find in those m nearer the surface. In mountain rocks, ther family, more durable in their texture than a any of the rest, showing that they have bee *ginally formed* under greater resistance, and *sequently* by more intense action; and yet

parts, (for, generally speaking, they are compound rocks) than the others. These rocks are the granite family, composed of quartz, felspar, mica, and hornblende, though not always in the same proportion, or all contained in the same portion of the rock. Those granite rocks, in almost every situation in which they appear, seem to have been thrust up from below by some violent action too deep in the internal parts of the earth for coming to the surface with an open chimney like a volcano, but which, pressing upward in mass against the stratified rocks, have bent them upwards, twisted them in all directions, and ultimately torn them asunder, and risen in giant mountains over their level, though occasionally bearing fragments of the strata on high, along with them. From the resistance, the depth, and consequently the vast force by which those formations have been sent upward, we may well suppose, that when they reached the surface they were in a state of intense heat, such as was sufficient to consolidate every stratum near them, to turn accumulations of sand and shells into mountain limestone, and consolidate deposits of soft clay into that durable clay state which we meet with in many of the mountains. It does not appear, however, that those granites have been liquid at the time of their ascent; although there are some places where they appear to have bubbled over the sides of the granite formation itself in a sort of layers, though not exactly stratified, which are known by the name of gneiss.

That the action has been exceedingly powerful, we can readily suppose, for those granitic mountains are the most rugged in their forms, and sublime in their outlines, of any with which we are

acquainted. They form precipices of vast extent, scooped cavities, pinnacles shooting up several thousands of feet, and quite inaccessible by man, and a variety of strange forms; while their structure is so firm, and they resist even the frost so much better than most other rocks, that we can hardly suppose those inequalities of surface to have been the result of any surface action.

And we have another corroboration of this: granites in some of their varieties, or indeed perhaps in any of them, are not confined to mountains. They are found in districts comparatively low, and covered by other matters, though in general, if indeed not always, they stamp their own peculiar character upon the surface, clearly showing that they have been the most energetic agents in giving it its form. Sometimes the base of the granite is covered by a vast accumulation of gravel, which gravel generally contains a considerable admixture of clay; and in this gravel there are sometimes huge masses of granite completely detached from the rest, which frequently appear as if they had been worn by rolling in water. There are examples of this kind in the low grounds eastward of the Grampians; and some of the fragments are of such size and weight, that, though all the rivers which now flow in Scotland—and they are not few, in proportion to the size of the country—were combined into one stream, that stream could not move these masses a single inch.

No instance of those more mighty movements of the internal powers of the earth, by which rocks of the granite family have been produced and *elevated* above the mean level of the earth's surface, *or simply* above that of the bed of the ocean at

the place of their production, has occurred within the recorded annals of history. We are thus unable to form any notion of the manner in which it takes place, or of the phenomena by which it is accomplished. The probability, however, is, that the force of internal heat is the moving power by which it is in all cases raised above the level which the materials occupied; and as the resistance to this power increases rapidly with the depth at which it has to operate, we may suppose that the more mighty operations of this kind affect within certain limits the form of the globe. This internal force, though it is equal to the elevation of a new continent from the very depths of the ocean in one place, cannot destroy the tendency to gravitate in a single particle of matter. That tendency is inseparable from our most elementary notion of matter; and though as a passive force, or force tending to produce rest, it may be overcome in a portion of the matter of the earth for a time, yet it always holds the whole mass exactly balanced. An elevation of any part of the surface must, therefore, if of considerable extent, be attended with depressions of other parts; because if the matter of the earth gives way to the active force in one direction, and the force ceases to act so violently in other directions, the matter there must press with a sort of recoil upon the diminished force, by means of gravitation alone. Hence if we are to suppose that a whole continent, or large portion, of land, is elevated above the surface of the sea by this internal action, another part will be depressed; and thus exhausted lands may be taken under the *surface* of the water by the very same *operations by* which new lands are produced. We

are not to suppose that the strata which are deposited even at the bottom of the very deepest seas are all equal in consistency and strength; and therefore, if we are to suppose new land to be raised even from several miles' depth of water, we must not conclude that this land will rise with a uniform surface; but may contain basins and hollows by means of which portions of water could be elevated along with the newly formed land, and thus supply it with the requisite humidity, until it had acquired the requisite vegetation for carrying on the common functions of the surface as we observe them. It is useless, however, to enter into any speculation as to the manner in which those more mighty operations of nature take place; because as there are no direct facts upon which conjectures can be founded, they lead to no useful purpose, and there is no limit to their numbers.

If we take the granites and those rocks which more nearly resemble them, there is a gradual transition from them to those volcanic rocks which have evidently been formed nearer the surface, and by the action of heat under less powerful resistance. It has sometimes been customary to class these and other rocks as if they were of different ages,—one, for instance, being called primary, because it is composed entirely of crystals; a second, transition, because it is composed entirely of fragments; and a third, secondary, because it appears to be composed of earthy matters, reduced to portions sufficiently small for being deposited by water. There are also other theoretical distinctions; but they are all subject to this objection, *that they* rest upon an assumption of that of which *no man* can have, or by possibility obtain, anything

like real knowledge. The most prevalent of these, we believe, sets down granite, especially that granite below which no other rock has been discovered, as the oldest of the whole or the first formation; and when granite of nearly similar composition appears in veins, or overlaying other rocks, they suppose that such granite is a secondary formation, posterior to that of those other rocks, and also greatly posterior to that of the primitive granite. But all these theories proceed upon a partial view of the case, and generally speaking upon the supposition that all rocks which differ from the primitive granite, and perhaps even the primitive granite itself, have been formed by such action as takes place at or very near the surface of the earth. Now there lie two very strong objections to those partial views of the subject. In the first place, granite is no more a homogeneous rock than any of the others. It is indeed less so, and though its parts are compactly united, the different crystals and plates which compose its aggregate are more distinct from each other than the parts of those rocks which are admitted by the theorists to be of more recent formation. Besides, though in some cases granite does intersect other rocks in veins, and though in other cases there are stratified rocks below it, both of those circumstances, in so far as they prove anything, prove that the granite is the more recent formation of the two; and thus it is impossible to establish any law of primogeniture, among the modifications of the mineral kingdom, as they appear to us in those limited surveys which we are able to take of their positions with reference to each other.

There are very evidently traceable in those rocks

which come under our observation three distinct families: deposited rocks, of which the materials, whether in larger fragments or in grains, have been disintegrated from formerly existing rocks, and accumulated again, by surface action; rocks produced by deep seated internal action, of which the granites form the most remarkable specimen; and rocks formed by volcanic action nearer the surface.

We cannot say positively, however, that any one of these, taken as an entire family, is either older or younger than either of the other two, unless we can form a judgment of a particular case from the observed facts. If we find a rock which is evidently the product of surface action, which appears to have been infiltrated in veins into the cracks and fissures of a rock formed by subterraneous action, then we may conclude that the subterranean rock is the older of the two; whereas, if we find that the rock of internal origin has upheaved the strata of the surface-formed rock, or filled cracks or fissures of that rock, then we must conclude that the surface rock is the more ancient of the two.

No conclusion whatever can be drawn as to the absolute age of rocks, from the fact of their containing, or not containing, the remains of organic substances in a fossil state; because in rocks which are formed by the intense action of heat under the surface of the earth, whether deeper, as we have supposed to be the case in the granite family, or nearer the surface, as we have supposed in that of the volcanic rocks, we cannot suppose that any organic remain, though it should happen to get as deep as the granite, could retain any trace of its organisation there, or even in the less deeply

seated and less powerfully acting furnace of a volcano. All organised substances with which we are acquainted are destructible by the action of artificial fires; by which the volatile parts are dissipated, and the parts not volatile converted into their native earths, so as not to be distinguished in substance from those earths obtained by any other means. If the volatile parts are retained, and a sufficient heat applied, organised substances are converted into coal into fat or flaming coal, if the whole of the volatile parts are retained; and into blind coal which does not flame, if the more volatile parts can make their escape, and only those which are comparatively fixed are retained.

When, therefore, we endeavour to decide upon the ages of the different solids of which our globe, as far as it is open to our observation, is composed, we are reduced to very great uncertainty, let us take what new means of judgment we may. If we look at the mineral character of the rocks, we have already seen that either of the three great families may, in a particular formation, be either older or younger than the other two; and when we look at the fossils which they contain, we get no more certain information. It is true that if, as is the fact in many places, we find fossil remains of which not a living specimen now exists, in the same locality or any where else; then we can with safety conclude that this species, whether animal or vegetable, has become extinct. But, on the other hand, though we do not find a fossil remain of any animal in a particular kind of rock—that is, no evidence whatever *that that* species of animal did not exist at the *time when the* rock was formed—it merely proves

that there is no vestige of the animal in the rock; which is, in fact, proving nothing.

While, therefore, we cannot but admit that there is in the earth a power of renovating lands, or rather replacing them, by elevating new lands from under the water; and also of accompanying this operation by the depression of old and decayed lands under the bed of the sea; yet it is impossible for us to speak positively as to the times or the order of occurrence among those events; and consequently we must be careful not to assume wisdom upon the subject beyond our means of information, and thus beguile ourselves into error.

When those great changes of the globe take place, by which a new land in one place is substituted for an old land in another, we do not even know by how many stages or repetitions of this action the land may be brought into the state in which we observe it, or even into a state fit for animals and vegetables. It is highly probable, however, that this result in the case of a large extent of land is never arrived at at once; but that, besides those more violent processes of elevation and depression which upheave the surface in one place, and depress it another, there are more moderate operations which are not accompanied by any such signs of external violence. Judging from the characters of the soil, and from the matters contained in it, there is reason to believe that great part of England, of Europe, and of almost any country which has been examined, which are now at some elevation above the surface of the sea, have been at one time completely covered by its waters. From the numerous remains of fishes and deep sea shells, and other products of the ocean,

which are found in what are now among the most elevated parts of the midland counties of England, there is every reason to conclude that they have once been not only submerged, but under a very considerable depth of water, from which they appear to have been elevated without the operation of any surface violence; for there is no appearance of volcano or violent disruption of the strata, or any of those concomitants which usually mark violent action near the surface in the elevation of land. So also in the clays, and other formations not so elevated, and not so concentrated, but which are now above the mean level of the ocean, there are the remains of many aquatic inhabitants.

In such cases as that which we have now mentioned, there seems to be evidence of at least two elevations of the land above the surface of the water: first, of those central parts which contain the deep sea remains; and secondly, of those toward the shores in which inhabitants of the sea shore, inhabitants of the fresh waters, and probably also at least occasional inhabitants of the air and the land, have their remains blended together. It is probable that much of these latter formations has been produced from the decomposition of the interior heights; and the sand having been carried farther to seaward than the clay, upon which, though it is slow in depositing, the current has less influence when the deposit is formed, and forming the extensive sands which are found so abundantly on the shores, in a state of such comparative purity that they answer for the manufacture even of the finest glass, without any artificial refining.

The elevations and depressions, general or local, *which we may* suppose to take place from the

various internal actions in the globe, may be supposed sufficient to account for all those various positions of the stratified rocks which they could scarcely have received when deposited from water. In countries where there is no very great diversity of surface, the strata often maintain the same inclination for a very great extent; but in all cases where there have been violent and irregular elevations of unstratified matter, the strata are very much disturbed. Sometimes those disturbances have produced a downward bend, as if the strata had been deposited in a basin, and there is no doubt that there are many such deposits, of which coal often forms a component part. There are other cases, however, in which the basin appears to have been formed after the strata, because the latter are found full of cracks and fissures, which are sometimes filled with matter which has apparently been infiltrated from below, and at other times with matter which seems to have been ejected from beneath. Now we can easily understand how such an appearance might be brought about, by the ascent of heated materials from below. Some portion of these materials might be converted into gas, a state to which it may be said every substance can be brought by the application of some means or other; and the elasticity of this gaseous part, kept in powerful action by great heat, might form a large cavity, having the strata over it, and supporting them for a time; but as the whole cooled down, it is equally natural to suppose that the elasticity might give way so far as that the weight of the strata, together with the weight of the atmosphere, might be sufficient to bend down the stratified covering into the cavity in which the

gaseous matter had been in a great degree condensed.

We have examples bearing some approximation to this on the surface of the moon, when that luminary is examined by telescopes of sufficient power. There are then vast circular pits, measuring as much as forty miles in diameter and four miles in depth, which are usually contained within a circular elevation, as if an immense bubble had burst; and as the moon possesses neither atmosphere nor water, the surface agencies, there cannot modify that internal action which reaches the surface, in the same manner as it reaches the earth.

Besides the mere changes in the positions of strata which appear to have been produced by the action of the unstratified parts, whether those parts have reached the surface, and become visible or not, there are others nearly allied which produce at once a fracture and a change of elevation in the strata, without materially altering their general slope, at least for some considerable distance each way. These are called "faults" by the miners; because, if the mine is for the working of a substance which lies in beds, there is always a chance that the miner may be taken at fault, and not find his mineral again, even after he has worked his way through the interruption. If the interruption is thin, and does not disturb the elevation of the strata, it is usually called a "cutter," and if thicker, it is called a "dyke". When it is a fault, a skilful miner, if familiar with the strata above and below the bed which he is working, can generally tell *whether he is to* seek upwards or downwards for *his lost bed of* mineral; but there are other cases

in which it is by no means so easily got the better of. Sometimes also there is a mere slip, without any opening, and at other times there are matters in the opening which have, in all probability, been introduced from the surface.

Metallic ores are often found in fissures of this kind, interspersed with crystallised matters; and in many instances those veins vary greatly in width, and also in the quantity of metal in their contents, both at different parts of their lengths and different parts of their depths. In many cases those metalliferous veins have evidently been filled after their formation in the rock; but there are other cases in which one would be led to suppose that both formations had taken place at nearly the same time.

We have already observed, that there is some resemblance between the two families of unstratified rocks, though there is in the more characteristic ones a well marked distinction between those formed at great depths and those formed near the surface. The former, or the granites, are never crystallised or columnar in their whole structure, or a compound portion of it, though the individual materials are crystals; they are always massive and irregular in their forms. The volcanic rocks, whether they belong to one formation or another, have on the other hand their component parts blended together, and the compound pieces very often assume a regular form. On this account, they have been called "trap" rocks, from the Swedish name for a stair, as the slopes of them generally appear in steps one rising above the other. There are, however, some intermediate ones, in which the one has a resemblance to the other. The last of the granite family is

that which is termed sienite, which is chiefly composed of only two of the component parts of granite, hornblende and felspar. There are, however, some varieties, and even the original one, the granite of Syene in Upper Egypt, which contain the other ingredients. The sienites of this country consist chiefly of felspar and hornblende; they are much more kindly to work than the true granites, but perhaps not quite so durable. The first of the trap rock which approaches this one in its characters, is one of the porphyries, containing large crystals of felspar; but the porphyries sometimes contain sulphate of iron in crystals, which is never contained in any of those rocks which are understood to be formed at a greater depth.

If we leave out the common surface lavas, of which the formation has been observed in the eruptions of existing volcanoes, perhaps the nearest approximation which we meet to melting in a common furnace, is that which occurs in basaltic rocks. Basalt is usually compact and hard, and rings something like metal when struck with the hammer. Its fracture bears a very slight resemblance to that of glass, or rather to very highly burned pottery, in which there is a mixture of iron; and it is not unfrequently formed into natural columns of great beauty. These columns consist of varied numbers of sides, and there is generally an assemblage of them in close contact, but not united. They consist of jointed pieces, which are sometimes straight and sometimes bent, but always very neatly fitted the one part upon the other. There are splendid specimens of them, which are much admired from their *fancied* resemblance to ruins of gigantic structures *of man's* erecting, in the north of Ireland,

and at the isle of Staffa. There are many ot scattered through those parts of the country w contain volcanic formations, and not unfrequ they appear to have been projected upwards, at all events poured along in a liquid state, in and fissures of the earth; for, in many parts o island of Mull, towards Staffa, the surface is i sected by lines of them extending miles in le which seem at a distance as though they wer closures formed by human art.

But in treating of the mineral kingdom, th hardly any end of those productions which we with at the surface; and as we have reason t lieve that the grnd causes of their formatio that is, of their change tnto their present form deep in the earth, the philosophy of them is vague and difficult. But there is enough disc able by the most common inquiries, to convin that the Almighty has not left himself with witness in the mineral kingdom, any more th those productions which grow and live; and there are powers of preservation, renovation reproduction, in the great globe of the earth i as well as there are in its vegetable and a inhabitants.

CHAPTER IX.

FLUIDS—ATMOSPHERIC AIR—WATER.

It is not our intention in this chapter to i tigate the nature of all the different fluids w *exist*, whether in the liquid state, distinguis *from air*, or though colourless visible by the

tion or reflection of light, or whether existing in the state of gas or air, in which few of them are discernible by the eye, though some of the more weighty ones, such as carbonic acid gas, can be poured from one vessel into another. Those liquids and gases are only forms or states of matter, and it by no means follows that a liquid or a gas differs from a solid in the essential substance of which it is composed. The chief difference, apart from those compositions and decompositions which have really nothing to do with the change of state, is that the liquid is more under the influence of the repellant or separating action of heat operating upon its particles than the solid is; and that the gas or air is still more under this influence than the liquid. It only requires, however, a sufficient withdrawal of this operation of heat to bring the gas back to the liquid, or the liquid back to the solid; and the application, or renewal of an adequate action of heat will produce the changes the other way.

Such being the case, it is impossible to comprise fluids in any perfectly general view; because the action, which is no doubt in part modified by their fluidity and the degree in which it exists still depends chiefly upon the nature of the substance, and not upon the state. Hence, in a mere sketch, it becomes necessary to limit the subjects of our consideration; and if we go beyond those two fluids which are most generally distributed around upon and in the earth, and descend to any others which have particular properties, there is no fixing of any point at which we could with propriety stop, unless we involved ourselves in the whole chemical structure and action of matter.

Those two general fluids are water and atmo-

spheric air. The first is palpable to the senses, and possesses some cohesion of parts, or rather a cohesion of mass, all the individual parts of which can move among each other with great freedom; but of which the cohesion is rather the result of general attraction than of any particular attraction in the subject itself; because water will not remain on a slope without a support capable of resisting its pressure, and when it is free to move and dispose itself according to the law of its distribution, the form which its surface assumes is always that of the mean surface of the earth, and if this equilibrium of surface is disturbed, the water is agitated and endeavours to return to its level.

The other fluid, which exists as a gas at all temperatures, just as water exists as a liquid at moderate ones, invests the earth on all sides, and reaches to the last elevation from which the most glimmering ray of twilight can be reflected from a sun-beam falling obliquely upon it, and to what distance beyond this it may fire off into the regions of space, we have no means of discovering; for if the light of the sun, or indeed light generally, will not reveal anything to us in its substantive existence, we have no remaining means of obtaining any knowledge of it except the knowledge of the effects which it produces.

Of those two fluids, water is the one with which our senses are, upon the whole, most conversant, because it has the greatest body and weight; but though this is the case, water cannot act its part in maintaining growth and life upon the earth without the agency of atmospheric air; and therefore it becomes necessary to have some knowledge of the constitution and action of the atmosphere, before

we can rightly understand those of water. We shall therefore proceed with it.

ATMOSPHERIC AIR.

The atmosphere is composed of two gases, not as is understood in a state of chemical union, though so internally mixed that it is not possible to discover that there are two component parts in it, unless by the application to it of something which separates the one of those parts and leaves the other. Those component parts are oxygen gas and nitrogen gas, of which the compound contains in bulk very nearly one-fifth of oxygen and four-fifths of nitrogen; but if we estimate them by their gravitation or weight, which is the true measure of their quantities of matter, the oxygen is in greater proportion to the nitrogen than one to four, because at the same temperature oxygen is specifically the heavier of the two.

Though these elements are merely mixed, and not combined, it does not appear that any mere action without the assistance of some substance having a greater attraction for the one of them than for the other, can make them separate; for in all degrees of ordinary temperature, in all variable states of moisture, under all varieties of pressure, and consequently of condensation, and at all elevations above the mean level of the earth's surface, where observation has been made, there is no apparent difference in the relative proportions of those ingredients.

For reasons presently to be mentioned, the weight of atmospheric air is a very variable quantity, and cannot be expressed in any measure, that is in terms of the weight of any comparatively *invariable substance*, unless the circumstances

under which the weight is ascertained are state the same time. The chief circumstance is degree of heat; there may be others, but t effects are small in comparison, and, as applie the atmosphere generally, we have no instrum fine enough for taking cognisance of them. N if we suppose a common thermometer to be form in its degree of temperature, one hun cubic inches of atmospheric air at the tempera of sixty degrees of the common thermometer, we just about thirty-one grains, which is at the ra thirty-one hundredth parts of a grain to the c inch. This is a very small weight certainly; still it is one which produces very visible, when the great quantity of the air is taken consideration, very decided, and in some instai very terrific effects. It has been ascertained, in mean states of temperature, and nearly at mean level of the earth's surface, the pressu the atmosphere is nearly equal to fifteen poun every square inch of surface. If we were to di this fifteen pounds expressed in grains, by fraction of a grain, which expresses the weig one cubic inch of air, it would give us the h of the column of air, upon the supposition tha density at all elevations were alike. This, how cannot be the case; because air, like all gase possessed of elasticity, so that in proportio weight is placed upon it, it is squeezed in smaller space, and consequently is denser, it fol that the air must be pressed by the weight of remaining part of the column, up to the top of atmosphere, wherever that may be, which is a *it. In* consequence of this, the density *diminish* more rapidly than the height incre

and in fact as the air presses downward by surfaces, if we suppose it composed of successive strata, the densities at different elevations must have the inverse ratios of the squares of those elevations, that is, the decrease of density at different heights must be as the products of those heights, each multiplied by itself. There are many important practical lessons to be deduced from this, and one is a very easy method of ascertaining the heights of different places above the mean level of the earth, though the results in these cases require correction. Difference of temperature is the cause of the necessity of those corrections; because heat expands air or makes it lighter, and cold condenses it or makes it heavier; and the extent to which it is changed by any variation of temperature must be found by direct observation. Besides this, we must ascertain whether the instrument, the temperature of which is our guide to the temperature of the place, actually has the temperature of the free air of that place; and this is done by applying one temperature measuring instrument close to the instrument which gives us the air, and placing another freely exposed to the air upon all sides.

As consequences of this diminution of weight or density in the atmosphere as we ascend, there result some very important properties of that fluid. The rarer that the atmosphere is, it has the greater capacity for moisture, or can hold a greater proportion of water in the state of invisible vapour at an equal temperature. Now the temperature of the atmosphere does not decrease so fast by elevation above the earth's surface as the density does; and *hence there is*, in the atmosphere itself, and inde-

pendently of the operation of external causes, a means of ascent for that moisture which is taken up by evaporation from water and from other moist surfaces; and by means of this, the atmosphere acts as a sort of universal, though invisible, working pump, in raising water to such a height as that it may descend in showers to water the vegetation, and re-appear in springs and streams to supply drink to the animal world.

The weight of the atmosphere affords a general support to every thing which stands upon the earth's surface, whether rooted in that surface as a tree, placed on it as an inanimate object, or moveable upon it as an animal. We can form some estimate of the support which is thus afforded to a body of any known dimensions, by bearing in mind that the pressure on an inch at the mean level of the sea, and in mean states of the atmosphere, is about fifteen pounds. This is not a mere pressure downwards, like the pressure of one solid upon another which supports it. It is pressure from a fluid, and as a fluid is equally free to move in every direction, the pressure downward, upward, laterally, and in every imaginable direction is the same, or there is scarcely any difference of it for very small heights, such, for instance, as the height of a man; but every inch of the soles of his feet is pressed upward by the very same force as an inch of the crown of his head is pressed downwards; or, if there is any difference, the excess is upon the feet, inasmuch as they are nearest to the ground. On the whole surface of a man of ordinary size, the amount of this pressure is about thirteen tons, or nearly as *much as* a dozen horses would draw in well-con*structed* carts; but this pressure is internal as well

as external in all the cavities of the body which the air can reach; and therefore it is a support and not a burthen. It is more than this: for it is the resistance against which the living structures of the body work, when it is diminished, unless the diminution is counteracted by the constrictive power of cold, the body feels feeble and languid, and life drawls heavily on; and even when there is an exposure to severe external cold, under a very reduced pressure of the atmosphere, such as on the top of a high mountain, some of the more delicate internal textures of the body, and also the lips, the eyes, and the skin of the nostrils, and internal ears upon which the constrictive power of the cold cannot act, without a dangerous lowering of the temperature of health in the body, are apt to be disrupted, and to bleed.

The effect upon the vegetable tribes, though we are not aware that it tells upon any thing resembling an organ of sense as possessed by animals, is yet not less conspicuous. Besides the greater heat, and consequently the greater stimulus to the vegetable in low situations, there is the greater pressure of the atmosphere as a resistance or antagonist power, by means of which it can bring up its action to a higher degree; whereas under a diminished atmospherical pressure, the plant cannot work so vigorously for want of a sufficient resistance. We see convincing evidence of this as we ascend a lofty mountain from a low valley or level plain, not much elevated above the sea; for as we climb, vegetation becomes more and more dwarfed, until beyond a certain height it ceases altogether. Now, though the *difference of* atmospheric pressure is not the *sole cause of this*, it has much more influence than

those who have not carefully studied the subject would be apt to suppose; and mountain plants suffer more from the alternation of day and night than plants which grow in a denser atmosphere; and therefore it is wisely provided that their structures are smaller and more compact, and that their growth is smaller.

The pressure or weight of the atmosphere is proved by many experiments, and by none more than when one substance is applied to another without any air between them; for in that case the pressure of the atmosphere retains them in contact with a force equal to that which has been stated. One of the most familiar, though not the least satisfactory, illustrations of this kind, is a plaything which boys call a "sucker." This sucker consists of a circular bit of leather with a string inserted in the middle of it. The leather is moistened with water, and pressed so firmly to the surface of a stone as completely to exclude the air; and then the stone may be lifted by taking hold of the string. In this case however it is difficult, if not impossible to make the exclusion of the air perfect, and therefore the sucker will not lift fifteen pounds for every square inch of its surface, though it lifts enough to prove the fact that it is held on by the pressure of the air. The fact of drinking water from a well by means of a straw from which the air is sucked by the action of the mouth is another proof of this; and it brings us very nearly to the principle of a common sucking pump. If the valve of the pump, which is placed in the plunger, or ascending and descending bucket, which fits exactly into the pump, is made air tight, or rendered so by pouring a quantity of water over it, every time

that this plunger is sent down by raising the handle of the pump, a quantity of air is removed from the bore or barrel, and the pressure of the atmosphere upon the surface of the water in the well or cistern, into which the lower or open end of the pump is inserted, forces up as much water as supplies the place of the air which is removed when the sucker is raised by pressing down the pump handle. In this way, every elevation of the handle removes a portion of air, and every depression of the handle causes as much water to enter the pump-barrel, as exactly occupies the place of the dislodged air. Thus, after a certain number of strokes or workings of the pump, greater in proportion as the water is originally farther from the sucker, brings the water entirely up to that part of the engine, where it is raised by the pressing down of the handle; and after this the same pressure of the air causes the pump to send up water, and continue to do so, until the surface of the water in the well or cisterns gets lower than the opening at the bottom of the pump-barrel; and after this, air is pumped up, and no more water can be obtained. As it is the pressure of the atmosphere which causes the water to rise in the pump, the height, or depth, from which the water can be raised, cannot exceed the whole pressure of the atmosphere; and thus the utmost extent of depth to which a pump of this kind can work must afford a measure of the pressure of the atmosphere; and, as the pressure diminishes as we ascend above the mean level of the sea, it must follow that a pump placed at a great elevation, as for instance on the summit of a high mountain *must be* unable to raise water from so great a *depth, as one* which is placed lower down. Expe-

rience shows that at the mean level of the earth, the height from which a pump can raise water varies from twenty-nine to about thirty-three feet, according to the state of the atmosphere. The pump is, however, a clumsy apparatus; and therefore recourse is had to more delicate ones. The chief of these is the common barometer, or weather-glass, which consists of a glass tube more than thirty-three inches long, and closed at the top, but open at the lower extremity. This lower extremity is either plunged in a basin in which mercury is contained, or it is bent upwards, and expanded into a vessel of considerable size, which has a perforation in the upper part to admit the air. In making the instrument, the tube is completely filled with mercury, and in order that the instrument may be accurate it is necessary that the mercury should be absolutely pure. When filled, the tube is inverted, the lower extremity being kept close until it is under the surface, if it is to be inverted in a basin of mercury; but simple inversion is all that is necessary when the tube is bent into a vessel where the mercury can present an upward surface to the air. In either case, as soon as the inverted instrument is placed in a vertical position, it will readily be understood that it becomes a balance, and one of a very nice and delicate nature, inasmuch as the mercury, if pure, slides in a glass tube with very little friction. The column of mercury in the tube which is closed at the top, is the one weight, and the pressure of the atmosphere on the top of the exposed mercury is the other; and the difference in height between the column in the tube and the surface of the exposed mercury is the exact measure of the weight of the atmosphere. It

matters not what the diameter of the tube, and absolute quantity of mercury that it contains are, though it is desirable that the bore of the tube should be as wide as possible, in order that the mercury may have sufficient weight for being steady, and for having less friction against the sides of the tube; for it is the weight which determines the height, the quantity being determined by the section of the column, which always answers to an equal section of the atmosphere, and therefore it is, on this account just as accurate with one size of tube as with another. Whatever is the proportion between the surface of mercury in the basin or other reservoir which is exposed to the air and the section of the barometer tube, the one of these must always rise as the other falls, and fall as the other rises; and therefore a common barometer with a fixed scale can never point out the weight of the air with perfect accuracy, unless for that particular state of the weather for which it is adjusted. It gives an approximate, however, which answers for common purposes. The average height of the barometer in this country, nearly at the level of the sea is about thirty inches; but it varies with different states of the weather.

In consequence of those variations, the barometer is termed a "weather glass," and as such it is supposed to tell us before hand the kind of weather which is to come. This is a point upon which the people of a country where the climate is so variable as in Britain, and where human comfort depends so much upon the weather, are very open to impositions of all kinds, much in the *same way* as the ignorant in all countries, *are open to the* deceptions of those impostors, who

profess to reveal to them their future fortunes. The events of those fortunes are secrets to which philosophy affords no clue, farther than is given by the observed succession of events in past times, or deduced from the character of the individual. For this reason, every person is really a better fortune-teller for himself, or at least has the means of being so if he would use them, than all the soothsayers in the world; and therefore impostors who by judicial astrology, or by any other pretended occult art—which is in reality nothing but darkness concealing emptiness, ought to be held up to ridicule. It is melancholy to think, if one could be melancholy upon a subject so superlatively ludicrous, that, even at the present day there are professional interpreters of the stars even in the British metropolis; and that some of those impostors or fools (they must be the one or the other) are persons having no small pretensions to the details of science. They must however be merely surface men, without the slightest feeling of true philosophy; for no really philosophic mind would imbibe such an absurdity as a folly, or practice it as an imposition.

The desire to tell the future state of the weather, is a branch of this; and though there are certainly some natural means by which past experience may be applied in predicting what the weather shall be, much upon the same principle as we judge how a man will act in time to come, from what we know of his acting in times that are past; yet both these require a very intimate knowledge of the past before the judgment can be at all depended upon; and even with all the experience which can be acquired by the longest and closest observation, we never can be absolutely certain of the result.

because we never know that we are in possession of all the circumstances, or what new contingencies, of the causes of which we have never thought, may arise in future.

We have judged it proper to offer these few observations in mentioning that the barometer is generally kept, not for the simple purpose of showing the changes of weight or pressure in the atmosphere, but as pointing out the changes of the weather, from foul to fair, fair to foul, and the like. It may do this in some instances; but then its doing so is no function of the barometer. Considered in itself, it is a mere balance and nothing more; and one might as well expect a common balance hanging in equipoise with only one scale visible, and any weight in it (say one pound,) to tell the observer what sort of goods were in the unseen scale, as that the barometer should tell what particular change of weather is to follow any variation in the height of the column of mercury. The variation of the barometer is an effect, and as is the case with every effect, it points out what has already happened not what has still to happen; though by long observation of what does follow in the weather, after barometrical changes, we may come to a rude sort of judgment of experience upon the subject. An experience of this kind is local however; because the effects which follow barometrical changes depend on places and also on seasons; and therefore it is impossible to lay down rules for the whole earth, or even for so varied a portion of its surface as the British Islands.

When the column of mercury in the barometer tube *sinks down*, it points out that *the pressure of the atmosphere* has been diminished to the same *extent*. Thus, for instance, if it descends from

thirty inches to twenty-nine, one-thirtieth of the pressure of the atmosphere has been taken off by some means or other, which is equal to taking off nearly half a ton of pressure from the surface of a man's body; and the body becomes no bad barometer as to the fact of the change though not as to its amount, for the removal of this pressure makes it languid. On the other hand, if the barometer rises from thirty inches to thirty-one, it is merely a sign that the atmospheric pressure has been increased by its thirtieth part; and this also is told on the human body, by the bracing effects of the additional pressure.

This is really all which the barometer, considered in itself, can indicate with regard to the atmosphere, or any thing which the atmosphere may contain; and before we can carry this any further so as to turn it to useful purposes, we must investigate the causes to which those changes of atmospheric pressure are owing. In doing this we must bear in mind that the atmosphere is perfectly fluid, and that it everywhere surrounds the earth to the height of many miles above the level of the sea. It can, therefore, have a free communication over all parts of the earth; and as fluids have not sufficient cohesion for enabling them to resist the attraction of gravitation, they necessarily maintain a perfect equipoise at all places where they have a free communication.

In consequence of this perfect obedience to the law of gravitation, the atmosphere would remain every where, and at all times, perfectly tranquil; without motion and exerting the same pressure, if *it were not* acted upon by some cause external of *itself.* An external cause to act upon the atmo-

sphere must come from the heavenly bodies, from the earth, or from both; and the inquiry resolves itself into what this influence may be. It cannot be gravitation alone; for gravitation alone would act upon the entire atmosphere as a whole; and thus in no ways disturb or derange the different parts of it.

Very little observation suffices to show that heat is the grand agent which disturbs the temporary and local equipoise of the atmosphere. If we take an air-tight vessel of flexible materials, and partially fill it with air; and then hold it to the fire till the air within it becomes heated; the air expands and stretches it tight; and however strong the vessel is, we have reason to believe that there is some degree of heat which would burst it in pieces. There are many other instances familiar to our common observation, of the expansion of air by the application of heat; but the one which we have mentioned is sufficient in illustration of the fact, neither shall we examine the rate of expansion with different degrees of heat, because all that we want to establish and illustrate is the general principle.

We need not say that the sun heats both the earth and the atmosphere, because every one feels it; but in consequence of the relative positions of the sun and earth, and the motions of the latter, both earth and air are differently heated in different places, and at the same place in different seasons and at different times of the day. The earth is nearly a globe, and so also is the atmosphere in its general but indefinite outline; because the form of both is *preserved* by the same principle of gravita-

tion toward the centre of the general mass. The sun, which heats both at the same time that it illuminates them, is situated at an average distance of ninety-five millions of miles from the earth; and is so much larger than the earth, that the light and heat of the sun, which are the same beams, though they tell differently, act upon both earth and atmosphere in straight lines. The usual expression is that the sunbeams "fall" upon the earth or atmosphere; and this word may be used, if it is properly explained,—which explanation consists in its being distinctly understood that nothing falls in those beams which can in any way be regarded as substantive matter, and as such possessed of or affected by the principle of gravitation.

Those sunbeams must produce the most powerful effect both on the earth and on the atmosphere where they fall directly, and this is where the sun appears immediately over head to an observer. This place may for distinction's sake be called, the point under the sun. The sun, with reference to the earth in our observation at least, maintains its position fixed and immovable; but the earth has two motions which, as we can observe the sun, but not the earth as a whole, tell to our observation as one variable motion of the sun. The rotation of the earth eastward on its axis once every twenty-four hours, causes the sun and the point under the sun to move westward round the earth during the same. The earth's annual motion round the sun is performed in a path which forms an angle with an equatorial plane or level surface supposed to divide the earth equally everywhere between the *poles or the* extremities of the axis of its rotation;

and for this reason the point under the sun, besides travelling westward round the earth every day, travels northward during one half of the year, and southward again during the other. This motion which takes a whole year in the performance—and which after all is not in absolute extent of distance upon the earth's surface going and returning, equal to more than half the measure round the earth, or half the distance which the point under the sun travels daily—is lost to our momentary observation in the latter and more rapid motion. We see it, however, after considerable intervals of time; for after the shortest day in winter is passed, we soon observe the sun coming northward and northward nearer to the point overhead, as midsummer is approached; and after midsummer we can in the same manner, if we take it at intervals, observe the return toward the south. We might also observe that the motion northward or southward is very slow at the beginning, increases toward the middle, and becomes slow again toward the end; but we are not in the meantime to enter so minutely into the matter as this. All that we wish to explain is, the motion of that point upon the earth's surface, which marks the greatest influence of the sun both upon the earth and the air. It travels round every day in the way we have stated, but with a little inclination northward during the one half of the year, and with a little inclination southward during the other. This daily inclination northward or southward, is not very great for a single day, even at the middle of its course each way; but still in the period of the year it varies nery nearly forty-seven of those degrees, of which the *measure round* the earth contains three hun-

dred and sixty, from south to north, and the same from north to south back again, in the course of a year.

From this it will be readily understood how this point under the sun, or point of greatest action of the sun, varies its position on the surface of the earth, and consequently through the atmosphere to the earth's surface, in the course of every year. But as the year does not contain an exact number of days, or even a fraction of a day in addition to the three hundred and sixty-five entire ones, which can be accurately expressed by numbers, the annual motion of the point starts from a different position in the south, at the commencement of every year, and from a different point in the north, at every Midsummer; and as the fraction, though not capable of being correctly expressed, is very nearly six hours, or a quarter of a natural day, or time of rotation on the axis, the starting position is always about one-fourth of the earth's circumference further to the west every year than in the year preceding.

When in this and the former case we speak of the point travelling westward, as if from any spot on the earth's surface, we are to understand of it as travelling the whole way round till it comes to the same point back again from the east. There can however be no misunderstanding in this, if it is borne in mind, that "from" and "to" are the opposites of each other as applied to the same motion, "from" pointing to where the motion begins, or the direction in which it comes, and "to" pointing to where it ends, or the direction in which it *goes*. Consequently, motion westward, or to the *west* is always motion from the east.

The influence of the sun, both upon the earth and the atmosphere is greatest at this point, and it diminishes, in its momentary influence, equally on all sides as we recede from this point, until we come to the boundary, at which it has no influence at all ; and which, were it not for the atmosphere, would be always the line dividing the enlightened half of the earth from the dark one ; and the boundary between these, unless for the atmosphere, would be perfectly defined, and sunset would every night produce the same effect, as the extinguishing of a candle in a dark room, or even in a coal-mine far under ground, which last is the nearest approach to absolute darkness, of which we have any example, and a stranger who experiences it for the first time, literally feels as if the darkness were pressing him closely on all sides, so that he feels doubtful whether he can move even a finger until the first shock of the surprise is over.

This effect of the atmosphere in sending down light, which otherwise would not reach the earth's surface, is called refraction ; and it is so abundant immediately at sunset, or before sunrise, that when one is in the shadow, one is not sensible of the moment at which either of these events takes place ; but it gradually fades away, and in the end merges in the darkness of night, which is never, however, total darkness. This takes place at about eighteen degrees of the earth's circumference beyond the illuminated hemisphere, or before the rising, and after the setting of the sun. It is called dawn in the morning, and twilight in the evening ; and when the sun passes directly over head, it is an *hour and* ten minutes in length ; but it is *always longer* in every other situation ; and in

countries very near the poles, it is several days in length, before the sun makes its first appearance in the summer, and after that luminary takes its departure for the winter.

The light of this reflected twilight is not quite so warm as the light of the sun, because the sun-beams as heat and light are not refracted in exactly the same direction; but still, some advantage in the way of heat is derived from atmospheric refraction by those who live in high latitudes, and have the sun always low even at mid-day.

We need hardly mention, that the effect of the sun-beams must be to expand, as well as to heat the atmosphere at the point under the sun; and this is the principal cause which puts the atmosphere in motion, and makes it a means of distributing over the whole surface of the land, that water which it takes up by evaporation. It would be of little avail to inquire into the actual heat at this place of its maximum, or into the rate at which it diminishes, as we approach the boundaries of the enlightened hemisphere; because the different surfaces of the earth itself, modify the influence upon the atmosphere to such an extent, that it is difficult for even the most nice inquirer into the details to say how much of the effect at any one place, is owing to the one cause, and how much is owing to the other.

Neither is it the point exactly under the sun, that is, the point where the sun is overhead for the instant, which is most strongly heated. Heat, though an energy which is rapid in its action, is still a created, and therefore, a finite energy, and consequently it *cannot* produce its effect until some time elapses. *In* consequence of this, the point of greatest heat

is always a little to the eastward of the sun, and the warmest time of the day, with the same state of the weather, is always some time after noon. How much after depends on the circumstances of the locality, but it is always some time after.

When the air is rarefied at this heated portion of the earth, it of course becomes specifically lighter than that air which is not so rarefied; and it is pressed up by the denser air upon the same principle as a cork is pressed up by water poured round it when it lies freely in a basin. The parallel, or portion round the earth, along which the place of greatest heat travels, for the particular day is necessarily more heated than those portions of the surface which lie to the north and the south of it; and consequently, the air over the whole of it must be warmer, and therefore rarer. Hence the constant tendency of the air upon the earth's surface, is southward and northward towards the parallel of greatest solar action for the time; but as it approaches that parallel it ascends gradually, because it is gradually heated and rarefied; and therefore there is a considerable space on each side of the middle of the parallel, where the effect is not perceptible, and the air then is usually remarkable for its stillness, unless when disturbed by local causes.

There is one other circumstance which must be taken into consideration; all that is carried upon the surface of anything in motion, acquires the same rate of motion as that which carries it; and having acquired this motion, it is as stable as though both were at rest, and has no tendency to fall one way more than another. A person outside a coach feels this; suppose he sits on the front, if *the coach started* at once into rapid motion from

rest, he would be in danger of tumbling back; if it stopped suddenly after rapid motion, he w be in equal danger of tumbling forward.

The earth carries the atmosphere; and tl fore, notwithstanding those internal motions o atmosphere called winds, of which we are prepa to say something, the atmosphere revolves, ir general mass, at the same rate that the earth c and in consequence of this, if it were not that ferent degrees of heat change the weight of it thereby put it in motion, the same atmosphere w stagnate continually over the same places; that, over every city, every marsh, and indeed every fertile spot of the earth, it would speedily l pestilence. We thus see how many advant are derived from the susceptibility of atmosp air to change in volume by different degrees of To plants and to animals, atmosphere is " breath of life," literally and in its substance; figuratively, it is "the breath of life" to the w earth, in that susceptibility of which we have spoken.

When a globular body rotates or turns r upon an axis, and when it does so freely, this always passes through its centre of gravity or centre of the matter which it contains, it mus apparent to every one that, though the whole g turns round as one mass, the different parts must move with very different velocities, or deg of swiftness. The extremities of the axis of tion, or the poles as they are usually termed, sidered as mere points, simply turn round in position without performing any circular mo *through* space. The equatorial parts, or parts *way between* the poles, perform, during every

tion, a circular journey in space, equal to the circumference of the globular body at that part; and this in the case of the earth is its greatest circumference, and measures nearly twenty-five thousand miles; but for the sake of easily remembered numbers we shall say twenty-four thousand, which answers to a motion at the rate of a thousand miles an hour to any place at the earth's equator, or to any thing which is carried along with the earth in its motion there.

In considering the motion of the surface of the earth, and of the air as resting on the earth and carried along with it in the daily rotation, we are therefore to understand that the earth's surface and the air upon it at the equator, travel eastward at the rate of a thousand miles an hour. But as the equator is departed from, and higher latitudes are arrived at, the circumferences of the parallels become less and less (in the proportion of the cosines of the latitudes), and consequently the eastward motion of the surface diminishes in the same proportion. This diminution goes on till the poles are arrived at; and at them, the cosine of the latitude becomes equal to nothing, and consequently the rotatory motion of a mere point on the earth's surface there, and of a mere line in the atmosphere standing perpendicularly over this point, also becomes equal to nothing.

From this it follows that, as the air acquires the same rotatory motion as the earth upon which it is carried, if air from a higher latitude is carried to a latitude nearer the equator, it must arrive there with less eastward motion from rotation, than the *surface of the* earth has at the place where it *arrives.* *We* have already shown that, from the

action of the sun upon the atmosphere, there is
stant current both from the north and south
the parallel of greatest heat, the average p
of which parallel is the equator; but, from
currents of air from the north and the
moving towards latitudes which have greate
city in eastward motion than they have, it
by necessary consequence that those curren
be left behind, or to the westward of the
surface; but we feel from the moving of a
even of the hand, that a current of air, or
call it a wind, can be equally produced
motion of the air over a surface, and the mo
a surface against or under the air. Only,
to the air that we always refer the motion
we call wind, the wind occasioned by the
surface of the earth escaping eastward fro
current of air, will make that current ap
move westward.

Thus, there is produced in each hemi
that is, in the northern part and in the so
but shifting north and south as the par
greatest heat shifts with the seasons, a c
motion of the atmosphere on the earth's s
blowing from some direction between the
and the east in the north, and between the
and the east in the south.

These currents are what are called the
winds. Local causes prevent them from bein
conspicuous or very regular upon land; bu
are constant upon the broad equatorial sea
Atlantic and the Pacific. For reasons whic
been already mentioned, they are not perc
for some distance on each side of the par
greatest heat; and they shift with that pa

its annual motion in latitude. Upon the average, however, the northern trade wind may be said to blow from the north-east, and the southern one from the south-east. They are not felt in very high latitudes; because the influence of the parallel of greatest heat becomes gradually so weakened as to be overcome by local causes; but over a considerable extent of the oceans which we have named they are very conspicuous; and besides their use in giving circulation to the air, they are very serviceable to navigators, who, when they get into the trade-wind, can cross those oceans westward, for hundreds of miles, without ever touching a rope of their vessels.

This is a beautiful instance of design, of which one knows not whether most to admire the simplicity or the usefulness. Those winds are not changed into their westerly direction, by any expenditure of energy exercised upon the atmospheric fluid itself, for they arise simply and necessarily from the figure of the earth and its diurnal rotation; and yet they double the benefit of that circulation of the air round the earth, which is produced by the influence of the sun at the parallel of its greatest action. That influence acting alone, tends merely to bring the air to the equator from the north and from the south; but this effect of the earth's rotation is to make it, at the same time, revolve round the earth from east to west; and though upon the surface of the ground local causes prevent this circulation from being uniform, there is not the least doubt that in more elevated regions of the atmosphere the air circulates freely in this direction as well as in the other, or rather in the

resulting direction which arises from the joint action of the two causes.

In what has been now stated, we have alluded to only one part of the circulation, namely the beginning of it; but as every fluid constantly tends to preserve its equilibrium, and does preserve it whether at rest or in motion, at least after the motion has continued so long as to be uniform; it follows that, if the volume of the atmosphere is constantly moving westward over those parts of the earth which are near the equator, gravitation, which fluids must obey, will lay hold of it, and bring it back again in a counter-current, so as to keep up the equilibrium. Nor is it difficult to see how, from the simple principles of the working (and they are exceedingly simple), this counter-current must operate.

As the air which is heated and rarefied at the equator ascends, it becomes colder. It does this because great part of the action of heat upon the air is derived from the earth by reflection, or throwing back the beams of the sun; and also by radiation, such as we experience when we bring our hand near a warm brick, or any other substance which is hot, but does not shine or give out light. This heating power of the earth, has far more effect in producing the circulation to the parallel of heat than the direct passage of the sun-beams through the air; for air is so sensitive to heat, and moves off so rapidly from a heating cause, that heat passing through it, does not greatly increase its temperature, if it is free to escape.

In consequence of this, as the heated air rises

above the heating earth, or escapes away from the action of heat, it condenses; and if it were to remain over the same surface, and the heat of that surface to be removed, it would fall down again. But the heat on the parallel is kept up and constantly sending warm air from the surface, so that that which rises and is condensed, moves toward the poles in the upper air, and produces a counter-current in both hemispheres.

As these currents are the reverse of the currents which produce the trade-winds, it follows as a matter of course that the rotation of the earth must have an opposite effect upon them. As they come into higher latitudes, where the eastward motion of the surface in rotation is slower than the eastward motion which they had acquired in the regions of the equator, they must get eastward in advance of the surface in those higher latitudes; and thus become currents moving, or which is the same thing, winds blowing from the west. But the original cause which starts them from the region of the equator, tends to send the one current northward, and the other southward; and thus the counter-current of the upper air in the northern hemisphere is a south-west wind, and the corresponding current in the southern hemisphere is a north-west wind,—it being understood that each wind blows from the quarter alluded to, and consequently to the opposite quarter.

As the lower current, or current produced directly by the different effect of the sun's heat on the earth's surface, ascends into the atmosphere as it approaches the parallel of greatest heat; so the upper current, or that which is *produced more* immediately in and by the atmos-

phere itself, descends as it reaches the cold latitudes.

We have a proof of this in the weather of Britain, variable as that weather is from the irregular form of the island, the proximity of extensive lands on the east of it, and their absence on the west; for, notwithstanding these circumstances, which send us winds from all points of the compass in turn, the prevailing wind, even on the low surfaces, is from the south west. If we go to the mountain tops, which are above the level of many of the surface winds, we find a south wind almost constant; and we also find that this same south west wind batters those mountain tops with the heaviest rains which they experience; for though there are often great precipices on the north eastern sides of mountains, the western sides of them are always the most weather-beaten.

As the trade wind ceases to be felt in regions near the parallel of greatest heat, it follows by necessary consequence, that this counter current should cease to be felt as the regions of cold are approached. We find experimentally that this is the case, for in high latitudes the winds are exceedingly variable and uncertain, and their causes are invariably local.

In the case of local winds (for the details of which we have not space), the principle is exactly the same as in those general winds, of the causes and motions of which we have given a hasty sketch. Wherever the air is heated more than at another place, it will ascend, and the cold air will blow inwards upon the surface to supply its place, and so produce a wind; and the violence of this wind will be in proportion to the extent of the warm and

cold surfaces, and of the difference of temperature between them. A room which is much warmer than the external air gives us a good illustration of this general action of the winds; for in such a case, if a chink of the door is opened, and one candle alight put close by the floor in the opening, while another is held as high in it as possible, the lower candle, if the difference of temperature is great, and the room large, will be extinguished by a wind blowing into the room, and the upper can-candle by a wind blowing out of it.

In the production of a wind or winds, for when one is produced, there must always be a counter one in some direction or other, it is of no consequence where the portions of air that are exposed to different temperatures may be situated. Hence, winds may, and often do, originate in the atmosphere itself. Thus, for example, if a dense cloud descends in air warmer than itself, a wind will blow from it in every direction; it is the same with those fields of ice which float about in the polar seas; for vessels may sometimes be observed, one sailing right before the wind, from one side of the field, and another sailing as right before the wind from the very opposite side, while the observer, at no great distance, may be lying perfectly becalmed, with not a breath stirring. A lake or pool, or even a thick and shady wood, may teach us a lecture on the philosophy of the winds, upon a sultry summer day, when the fields around are parched and hot, and not an air is stirring over them; for the lake, the pool, or the shady wood, on whichsoever side it is approached, will breathe a healthful breeze *upon the visiter,* strong in proportion to its own

size; and as the heat and stillness of the day 1 its refreshing influence pleasant.

Such being the case, we need hardly adc winds must play alternately between the se the land, in those regions, and at those se when the difference of temperature between and between the land during the day, and duri night, is the greatest possible. The sea, except it freezes, is never very cold on the surface, no its temperature vary much at different seas(the same latitude, while, unless in the sha there is scarcely a difference of temperatur(between any day and the adjoining night.

The land is very different, for when the s of the land is dry, it is rapidly and greatly l in places where the sun has powerful action. it is a law in the operation of heat, that substance which is easily and consequently r heated, is just as easily and as rapidly cooled. not be, however, in these cases, that the land gets colder than the sea during the night; b there is a great difference between the day anc temperature of the land, and this produces a sponding difference in the density of the atmo over it. Hence, when the land becomes l and the air over it rarefies and ascends, wl generally before mid-day, but varies with th(and the season, the sea breeze sets in, exceedingly refreshing upon the low and flat of hot countries, especially during the dry s when the ground, and every thing upon it, a great extent burned up. Late in the even at least at some time during the early part *night, the* sea breeze dies away, and ther

counter breeze from the land, which is seldom, however, so refreshing as that from the sea. Those sea and land breezes do not extend a great way across the country; nor does it appear that they reach to any great height in the atmosphere, for they are not felt beyond the first ridge of mountains, although those mountains may happen to be of no great elevation. In Britain they are most observable on the east coast, and in the early part of the season, because then the flat countries are usually dry; and though in some favourable situations the sea breeze plays along the shore, during the greater part of the hot weather, yet it is not general even on the flat countries, after the Midsummer rains. On the west coast of Britain, sea and land breezes are much less common, because the country there, is more irregular in the surface, and the climate is more rainy, and also because the south west wind from the Atlantic is much more prevalent, inasmuch as there is less action calculated to bring on a contrary wind.

As the alternate action of sea and land upon each other, on the small scale, produces those local and limited land and sea breezes, during the twenty-four hours, so the more extensive portions of sea and land, the continents, and oceans, produce alternating currents of longer duration, which get the name of monsoons, from a Persian word, signifying seasons, as those monsoons give the principal character to the seasons, in countries where they are prevalent. As they are produced by more powerful agents than the sea and land breezes, and also of longer duration, their accompaniments are of a bolder character.

In order, however, to have a correct understand-

ing of even the principle of those monsoons, it is necessary to advert to the seasonal changes of the parallel of greatest solar action, and also to the character of the land in the two hemispheres. It will be recollected that the centre of this parallel of greatest solar action, is about twenty-three degrees and a half southward of the equator, at the time of our mid winter, or shortest day; and that it is at the same distance north of the equator at our midsummer, or longest day. Each of these distances is more than a fourth of the whole distance from the equator to the pole, which is ninety degrees; and the extent of surface between each of them and the equator, is proportionally much greater than this. Therefore, the parallel of greatest solar influence travels over a large portion of the earth's surface. The maximum effect of the sun, even supposing the surface is equally susceptible to solar action, does not exactly coincide with the parallel for the time; because the annual change of the sun's place north and south, must take some time to produce its effect, as well as the daily change westward. In consequence of this, the maximum effect is always a little behind the parallel, over which the sun is vertical; but still the difference is trifling, and would hardly be worth mentioning were it not for the purpose of establishing the general fact, that every finite or created agent requires some time for the performance of its effect.

The solar action both upon the earth and the air must follow the annual motions of the parallel, in the same manner as it follows the daily motions of the point under the sun. When the sun is in either hemisphere, that hemisphere is more heated than the other, and of course the hemispheres are heated al-

ternately, the northern one during our summer half year, and the southern one during our winter. According to the general principle which we have stated, and which any one may verify, the lower current, or that which forms a wind blowing on the surface of the earth, is always toward the warmer surface. Therefore, during all the time that the parallel of greatest solar action is moving northward, there must be a movement of the general atmosphere on the surface toward the northern hemisphere, while, during the time that the parallel is moving south, there must be a movement of the same toward the southern hemisphere. The motion in declination, both northward and southward, is, however, as we have stated, a slow motion; and therefore the effect which it produces must take more time than if it were more rapid. Accordingly there is a portion of each half of the year, which is not much affected by those monsoons; and they come in differently, and produce different effects in different countries. Thus, though the monsoon from the south, comes from the hemisphere, having by far the most sea on its surface, and is, therefore, the one most loaded with humidity, it is not the rainy monsoon in all countries; for far to the south, such as in the country at the Cape of Good Hope, it is exceedingly dry, the wind of which it consists, blows for its whole course over the surface of water, and therefore, when it comes upon the land, as it has passed for no great distance through a warm region, it becomes a very drying wind. But when it gets beyond the equator on the north side, and has taken up a full charge of humidity from the polar seas, and the rivers and vegetation of the polar lands, it becomes a monsoon which breaks in the

most violent storms of which we have any experience. These storms are equally violent in the eastern continent, and in the western,—in India, in the rich parts of central Africa, and in central America, and the West India Islands; and there is perhaps no part of the world in which the change comes with greater violence than the west coast of the northern part of central America; for there the people are in some places obliged to quit for a time the towns immediately on the coast, and the land, to a considerable extent, is laid under water.

In countries where those monsoons are very decided, the turn of the monsoon is always the time at which the most violent weather takes place; and upon the average this is not far from the time of the equinox, when the solar action upon the two hemispheres is nearly equal. Even this, however, is rather after than before the equinox, because, some time elapses before the hemisphere the sun is leaving loses the benefit which it has derived in respect of heat, and some time elapses before the hemisphere in which the sun arrives makes up for the deficiency occasioned by the sun's absence. But when the equilibrium between the atmospheres of the two hemispheres is established, local causes are more left to their undisturbed effects in all latitudes than they are at any other season. This is the reason why in almost all countries there are equinoctial gales and storms, both in the spring and in the autumn; but as those gales and storms are produced by more local causes than the winds and storms of other seasons, they are more temporary in their duration, and more fitful in their direction. In narrow seas these are, therefore, exceedingly troublesome seasons for navigators; and there ar

some seas which cannot be navigated by vessels of European build without the most imminent danger. But when the sun declines so far into either hemisphere as to draw the monsoon after him, those causes of local disturbance are in a great measure subdued; and when the monsoon has spent its fury the weather becomes steady both at sea and on the land in those middle latitudes over which the monsoons chiefly extend.

In higher latitudes the alternations of summer and winter produce a considerable effect upon the winds. When the sun leaves a hemisphere, the polar part of that hemisphere soon becomes cold, and the air over it condenses and produces a general tendency of the wind toward the lower latitudes,—that is, a wind from the north in the northern hemisphere, and a wind from the south in the southern. But those winds are affected by the same causes which turn the trade-winds westerly, and they are consequently turned in the same manner; that is, into a wind from the north-east in the northern hemisphere, and a wind from the south-east in the southern. But those winter winds of the high latitudes are by no means so constant as the trade-winds near the equator, because the parallel of the greatest solar action is at a distance from them, and its influence upon them is comparatively weak. Hence local causes interfere not a little; and in those districts where the water is, generally speaking, frozen, and the earth covered with snow, which brings the whole country to a uniform surface, if that country is of considerable extent, the mid-winter is usually very calm and tranquil; and as the air is dry and pure in such places, the winter over the snows is not

unfrequently the most pleasant time of the year, while the never-setting full moon and the brilliant stars, whose light is reflected from the bright surface of the snow, make a tolerable substitute for the light of the sun.

Such are the general movements of the atmosphere with their causes, stated in brief outline; and we shall not notice those local disturbances, often of greater violence than the regular movements, such as whirlwinds, hurricanes, and the like; because though these are all explainable on the common principle of the motions of the wind, modified by local circumstances and temporary causes, yet they do not tend to throw much light upon the principle itself, which is the most important part of the subject in a general philosophical point of view. The uses of the atmosphere in the economy of animals and vegetables has been briefly noticed in former parts of this work; but we cannot pass over the beautiful application to each other of its two principal component parts, oxygen and nitrogen. These are not separable from each other by any change of state which can be produced in the air itself, but only by the application of some substance which will combine with and remove the one of them and leave the other. Oxygen is by far the most active principle, and enters into the greatest number of combinations in all the three kingdoms. We have seen that it forms an element in the simple earths; and there are remarkably few mineral substances which do not contain it in some proportion or other. No animal can live, and no vegetable can grow, without it; and therefore we may say, that while it is the most generally distributed substance in nature, it is

at the same time the most useful and the most active. Nitrogen has far less activity, and does not enter into so many combinations; and the instances in which it occurs among elementary substances are comparatively few. In many cases it appears to answer little other purpose than that of diluting the oxygen so as to prevent it from acting too powerfully upon the more delicate working structures, though from the activity of some of its compounds, and the fact of its forming a component part of animal matter, we may conclude that its positive uses are also highly important.

That the atmosphere which surrounds the earth should be composed of elements the most useful to the living and growing inhabitants of the earth, and one of which at least is the most active in all those changes which take place on the surface, is one of the most striking instances which we have of the perfect unity and harmony of the whole; nor can we have any more convincing proof that they are the production of One who knew the end from the beginning, and who fitted them for each other with a nicety from which we may learn wisdom, and must admire though we cannot imitate.

The perfect compound which they form, without the least tendency to separate in any of those changes of density or motions in place which make the whole circulate freely round and round the globe in every direction, and which union, close and constant as it appears when there is no necessity for dissolving it, is yet so easily dissolved, that the breathing apparatus of an animalcule, whose whole frame is not bigger than the hundredth or even the thousandth part of a pin's head, can separate without labour the portion of oxy-

gen which it requires, surpasses all wonder, and renders the structure of the air, simple as it is, one of our most delightful studies.

There is only one other general use of the atmospheric fluid to which we shall advert, and our notice of it must be very brief—that is, its agency as the distributer of water. This water it takes up in substance, but freed from all impurities from every moist surface. So taken up, it is diffused through the volume of the air; and those very motions which we have shown to arise from the constitution of the air itself, the direct and reflected influence of the sun, and the rotation and revolution of the earth, are the principal means by which this moisture is distributed to those places which require it.

The process of evaporation, by means of which humidity is raised into the atmosphere from water and moist substances, must be considered as an action depending more upon the properties of water than on those of air, for it goes on more rapidly in rarefied air than in dense air; and more rapidly still in a vessel from which the air is excluded. There are also many substances that pass more readily into vapour than water does; and the air is of much service in receiving and dissipating such substances. Water passes quickly into vapour when it is heated to the boiling point, but it evaporates at all temperatures, even when it is frozen. It passes the faster, however, the higher the temperature is; and in that natural evaporation which supplies the air with the greater part of its moisture, a good deal depends on the state of the air, in respect of density, temperature, quantity of moisture in it, and probably also electric state—

at least, there is most electric action in the form of lightning at those places and those times when there is the most active evaporation.

One principal influence of the atmospheric air upon water, appears to be the very opposite of evaporation—that of keeping the water in its place on the earth, but allowing all its motions to be freely performed. On this account the supplying power of the water is always greater than the receiving power of the air, unless it be when the surface of the earth is very dry, and then moisture can find its way to the air from very considerable depths.

The air thus regulates the quantity of water which is to be returned to the surface of the earth in rain or snow, as well as carries it to its destination. If all the vapour which the water could send up, were received into the atmosphere, the quantity of rain would be excessive, and the heat of the earth would be greatly reduced. The latter circumstance would be produced by the absorption of heat, or rather the occupation of a portion of the action of heat, which always takes place when vapour is formed, and which is always greater in proportion as the formation of the vapour is more rapid. This state of things might increase the growth of leaves in vegetables; but it would greatly lessen the production of flowers and fruits, destroy the flavour of the latter, and injure the quality of the timber of trees. If the early part of the summer is more than usually humid, we find that flowers are few and fruits tasteless; and when the autumn is very wet, the wood does not ripen, or the buds form properly, and thus the succeeding season is always one of inferior vegetation.

This disposition of the atmosphere to take up just the requisite quantity of moisture and no more, is therefore a great means of protection to the vegetable tribes, and through them to the animals. The evaporative power of the atmosphere conduces to the same end. Evaporation produces cold, and cold lessens the tendency to evaporation. Wherever the surface is more than usually humid, the atmosphere descends upon it from being condensed by the cold; and while it descends upon the humid place, it ascends from the dry one; and in consequence, the surface wind blows from the former to the latter, and carries the moisture along with it. This continues till the air over the dry place is saturated, and resists; and then a shower upon the dry place is the result.

Such is the way in which the atmosphere acts, in receiving, regulating, and distributing that moisture which is necessary for the economy of the earth's surface; and we shall next inquire into the state in which this moisture exists in the atmosphere, the means by which it is retained there, and the operation by which it is separated, so as to be returned again to the earth.

The moisture which the atmosphere contains, even when it is in the state of invisible vapour, and below the quantity of saturation, so that the air is taking up more, is not chemically united with the air, any more than the two principal ingredients of the air are chemically united with each other. Like them, it is in a state of too minute division for being detected by the eye or the microscope, and indeed neither the one alone, or assisted by the *other*, can detect any parts in water when it is *in a liquid* mass; but still it is only mechanically

mixed. We believe, indeed, that there is not, in nature or in art, a single instance in which a substance combines chemically with a mechanical mixture, without destroying the mechanical form; and conversely, there is no mechanical mixture that will, as such, enter into a chemical combination. We find oxygen in very many chemical compounds, and nitrogen in not a few; but we are not aware of a single chemical compound, of which atmospheric air is an element. It no doubt enters into mixture with many substances, with water for instance, whether fresh or salt. It is necessary to the existence of fishes, and of all animals that live in the water and breath by gills, that such should be the case; for every breathing creature requires oxygen, and we believe that the breathing apparatus of no creature is capable of so powerful an operation as the decomposition of water, so as to obtain oxygen from that. But independently of the analogy—which, however, is a good argument in this case, because it is universal, we have direct proof that the suspended moisture is only mechanically mixed with the air, in the ease with which it can be separated without any apparent action, by a very great number of substances. It is probable, however, that when the vapour is at first raised, it is not in a state of so minute division, as when it ascends into air which is more elevated and rarer. We see this in the case of steam and smoke, the aqueous part of both of which being visible when it is first raised, and then gradually melting into the air; and we see it in that tremulous motion which dances on the crests of heights, and even around the tops of trees when there is a rapid *evaporation, but* of which there is no trace, even

at a very short distance from the object which supplies the vapour. This continued division of even the invisible portions of water, after they are not only suspended, but actually ascending, in the atmosphere, is a continued evaporation, and requires some heat as well as the first raising of the vapour. The dispersing vapour thus tends to cool the portion of the air through which it disperses.

It is no argument against the mechanical mixture of vapour with the air, that the mixing requires a certain action of heat; for if a condensation takes place, whether chemical or mechanical, a certain degree of the action of heat is always set free; and if, on the other hand, there is an expansion, the action of heat is always required to support that expansion, by what name soever we may call it.

The next point is, how this vapour, which, how thinly soever it may be dispersed, is still water, is supported in the air; and the most probable answer, in a case where we cannot observe the fact, is, that it is by a sort of surface attraction, and more especially by that dispersive power in water, by which it passes into vapour in a vacuum, in which there is no air by means of which it can float. The action of heat is necessary to the observation of this dispersive power, for the hotter that air is, as well as the more expanded, the more water it can hold suspended in the state of vapour.

This leads us directly to the cause of the condensation of vapour into portions which are too large for remaining suspended, and which therefore ultimately descend in rain; though the warmer air *near the* earth generally evaporates them in part, *and often* dissipates them altogether, before they

reach the ground. When portions of air at different temperatures are mixed, they are not capable of holding the same quantity of water in the state of vapour, as they did when separate. In other words, less moisture saturates them than the parts, even if we suppose that there is no alteration of temperature. In consequence of this,—which is a fact that has been established by experience—it may happen, and does often happen, that though neither of the parts singly was saturated, there is more moisture in them than suffices to saturate the mixture; and whenever this happens, the surplus must form a cloud; but whether this cloud shall or shall not descend to the earth in rain, is another matter. If circumstances favour its descent, and it reaches the earth, it may be either rain or snow according to the temperature. If the temperature, where it is formed, and throughout its descent, is above the freezing point, or more than thirty-two degrees of the common thermometer, the collecting moisture will be frozen, and it will descend in snow; and it appears from observations made in different climates, that the colder the atmosphere is in which the snow cloud falls, the particles or individual pieces of the snow are the smaller. In the extreme north, there never falls anything but snow in an exceedingly fine powder, the particles of which will not adhere to each other; while in the last latitudes toward the equator, in which frozen water falls, it falls in large hailstones, which are sufficient to break the more tender shoots of the trees, and do a great deal of damage.

In Britain, especially those parts of it which are sufficiently far to the north, or sufficiently elevated for having a regular snowy winter, we have an exemplification of the states of the weather in which

snow descends in its different forms. When it comes on in a comparatively moderate temperature, it comes in broad flakes, which have a feathery appearance, float lightly, fall slowly, and very often melt almost as soon as they reach the ground. When the frost is at the utmost of its keenness, the snow is in fine powder, but very hard and dry, as one would say, and rises in the wind like dust, after it has reached the ground, curling into wreaths in the eddies, and leaving the exposed places comparatively bare. This snow does not melt so easily as the former ; and therefore, when a severe storm of it falls, the remainder of the accumulations often lingers till the middle of spring. In the less elevated parts of the country, this is sometimes accompanied by hail; but this hail always comes in those pauses during which the severity of the frost abates a little; and it is never of any considerable size. The characteristic time for hail-showers is nearer the summer than even that of flaky snows, being generally in the advanced part of the spring, and the early part of the summer, but sometimes, though more rarely, in the autumn. This we might expect from the natural circumstances of the two seasons. It will be understood, that what we call cold, far from being a substance. is not even action; it is the absence of action—a passive state as it were. In consequence of this, there is a marked difference between the causes, and therefore between the characters, of the spring and the autumn, which is well worthy of attention by every one who wishes rightly to understand the phenomena. The spring is the season of action, as during it the active powers are conflicting with the passive repose of the winter, and those powers acquire strength as the season advances; while in

the autumn there is a gradual abatement of action; and as the passive state can make no direct attack upon the active one, but must merely follow as that is withdrawn, we have none of those conflicts in the autumnal months which we observe in the spring. The signs of most severe atmospheric action are thunder and hailstones, though the action which they indicate is local, and not general. The great heat produced by the passage of the lightning, or electric action, causes a very rapid expansion of the air, and this expansion first causes a great internal evaporation in the atmosphere, or a demand by the heated and expanded air, for moisture from all the air around it. The air thus expanded, mounts up with a rapidity proportionate to its expansion; and as this is as instantaneous as the flash of the lightning itself, the subsequent condensation from the lateral pressure of the atmosphere occasions the thunder clap, which is more sonorous than if solid bodies struck against each other, because the air, as the proper medium of sound, is vocal all over, and vibrates from the place where the concussion occurs to the ear of the hearer. Sound, however, is a secondary action, produced by the vibration of that which sounds, and not by the cause of the vibration; and therefore, though it moves rapidly, it takes some measurable time to pass over a very moderate distance. The flash of the lightning is the immediate effect of the cause, without the instrumentality of any secondary object; and therefore our observance of it is much more instantaneous. But though lightning, and light in all its forms, is a primary effect, the cause of it is still created *and finite*; and therefore lightning or light *is not seen by* us at the very instant of its produc

tion, though, for such short distances as any which can occur within the atmosphere, the time which elapses between the actual display and our perception of it is so very short, that we can take no estimate of it by the finest instrument for measuring time, or even by feeling, which is far more delicate, and capable of estimating far more minute divisions, than any instrument that can be constructed. But those feelings of exceedingly small differences are of no use when we come to practice, and estimate quantities in terms of a definite standard, because we are unable to compare them with that standard, so as to find out what relation they bear to each other.

The portion of air which has been heated and expanded by the action of the lightning, and has in consequence taken up a considerable quantity of additional moisture, and ascended therewith into a higher region, is soon cooled and condensed to the same degree, as the general air in the place to which it has ascended. In this state it is unable to retain the additional moisture which it acquired in its heated and expanded state; and consequently, all that portion which it cannot hold suspended, is set free; and as both the absorption and the giving out of this quantity are far more rapid than in common evaporation, and the formation of ordinary clouds, where there is no lightning, this moisture falls at once to the earth; and falling from a greater height, it falls in larger drops than common rain, and also more partially, and not unfrequently it falls perpendicularly, before the lowest stratum of the air has been disturbed, and while all else is calm and tranquil on the surface. If the expansion and condensation are very great, and much of

the action of heat passes off in lightning from one cloud to another, an intense cold may be produced; and the moisture which is set free when the condensation takes place, may be instantly frozen. If such is the case, it of course falls in hail; and the hailstones are larger in proportion, as the climate is naturally warmer, or the season is farther advanced; because under these circumstances the requisite degree of cold cannot occur so low down in the atmosphere, as where the climate is colder, the season nearer the winter, and the line of congelation, or height in the atmosphere at which water freezes, is nearer the surface of the earth.

Thunder storms, accompanied by hail storms, are evidences that the atmosphere is playing at summer and winter; and as the effect of this is invariably the discharge of more moisture from the atmosphere than would have fallen in the same time if the rain had come without electric disturbance, the effect of these storms is always to raise the temperature, and to dry, or, as people say in ordinary speech, "clear" the air.

This clearing of the air is noticed by even the most unlearned of those persons whose occupations lead them to be familiar with phenomena of the sky; and therefore we may rest assured that it is perfectly true; for those natural effects, which all those who have no theory to support, agree in expressing in the same manner, must be correct, whether the parties happen to understand their causes or no. This is a remarkable one, and one upon which there are not two opinions among those whose opinions are worth the having--that is, among those who form their own opinions from *direct observation*, without being biassed by the

doctrines of any school; and therefore it is worth examining and explaining.

The explanation is very simple, if it be borne in mind that the formation of vapour, whether primarily from water or moist surfaces in the lower stratum of the air, or secondarily by internal evaporation in the volume of the air itself—either by more minute division, or by the abstraction of vapour by one portion of the air from another, (which last is the case in the thunder storm,) is always accompanied by the absorption of a certain degree of the action of heat; and while the moisture raised by evaporation remains suspended, the same degree of the action of heat remains latent, or occupied in keeping it there, and is consequently not sensible to our feelings or our instruments. But when the thunder storm, whether it sends down hail or snow, discharges more of the suspended moisture than would be suspended without the electric disturbance, the action of heat which kept this moisture in the suspended state, is set free and becomes sensible as warmth; which warmth diffuses itself in the atmosphere, and gives an additional evaporative power to the mass, by means of which the tendency to the formation of clouds is not only lessened, but clouds already formed are dissipated by this evaporative power in the air, and the whole becomes clear. What continuance of thunder storm may be necessary to produce this effect depends on the circumstances of the particular case. If these are local and temporary, which is generally the case with atmospheric disturbances in the latter part of the spring, the air over a *district* may be cleared by a single thunder clap, *and the* descent of one shower; or if the lower air

is dry, and the upper current comparatively steady, the cloud may be taken up and dissipated by atmospheric evaporation without the fall of any rain.

When the atmosphere is, in consequence of these electric disturbances, deprived of a greater portion of its humidity than it would part with without their assistance, it of course becomes a dry and drying air, and takes some time before it is saturated so as to form clouds by the contact of the ordinary currents; and from this we can easily see that if thunder storms occur when the earth is dry, and affords little moisture for evaporation, a continuance of dry weather must ensue; and this will be most remarkably the case when the thunder storm dissipates the clouds without any rain falling. It is evident that such must be the case; for with the same violence of electric action there must be the same separation of moisture from that portion of the air in which the action takes place, whether the moisture so separated falls to the ground or not. If it does not fall to the ground immediately under the disturbed portion of the air, it must be disposed and carried off by the currents, generally speaking by the upper current of the atmosphere, to other places. We find a verification of this in the weather of Britain; for when storms are very general, they most frequently begin in the south and proceed northward, even though the surface wind is from the northern part of the horizon. Local and temporary showers, however violent they may be for the time, do not appear to reach the upper stratum without their disturbing influence; and *therefore clouds* formed by those local disturb-

ances fall in those districts over which they are formed, and do not follow the course of any general current.

It is not very easy to understand, and consequently less easy to explain in popular language, the influence of electric action in the air, because we cannot reach those regions of the air in which it must be supposed to begin; and though we did, the air, and even the incipient cloud at its first formation, are invisible; and therefore we could not easily observe the beginning of their electric action. We know, however, that what we call electricity is a modified action, namely, the general action of heat modified differently by different substances, in the same manner as different substances modify it otherwise as light dry air, or air below the point of saturation with moisture, for we can have no knowledge of air as absolutely dry. Dry air is what is called an electric, that is, electric action does not pass through it; but may be excited in its surface by the friction of a substance capable of conveying this action; and water, even when divided into vapour which is invisible, is such a substance. Now we have only to suppose that there is a friction of two counter currents in the atmosphere, which do not immediately contain such a superabundance of moisture, above what the mixture of them can retain, as immediately to produce a rain cloud, and the moisture which is thus set free, even though it should happen not to be visible, may excite electric action; for it will be recollected that this action does not imply the consumption or combustion of any substance until it is brought up to the intensity of absolute fire, and then the com-

bustion produced by the lightning is a secondary action, subsequent to the production of the lightning itself.

It is highly probable that in the upper regions of the air, where, from the diminished pressure, disturbances must be much more easily produced, and motion much sooner commenced, than in the denser atmosphere near the earth, there is always electric action going on, the air answering to the glass, and the water to the conductor in the common electric machine. This, by the way, may account for many of those luminous meteors which appear in the upper air; and which may be young lightnings which have no sufficient supporting cloud, and not strength to reach the ground.

When the ground is exceedingly dry for a long course of time, and the influence of the sun beats strongly upon it, the lower atmosphere must of necessity get dry as well as hot; for though the heat increases the evaporative power, the supply is diminished, the moisture gets upward towards the upper current of the atmosphere, and the lower air becomes an electric or a barrier between the electric action of the upper heat of the sky and that of the earth. The lower air bears the same resemblance to the glass in a common electric jar, of which the moisture in the upper air answers to the coating on the one side, and the earth to the coating on the other; and the common experiments in electricity show that if a non-conductor is placed so as to insulate from each other two conducting substances, and if electric action is excited and imparted to the one of those conducting substances and *not to the* other, the one becomes technically *what is called plus* and the other what is called

minus in electric state,—in common language the plus one is in that state which disposes it to originate or give out electric action; and the minus one is in that state which disposes it to receive, or in so far as it is apparent to the senses, to terminate that action;—if electric action is thus excited, all remains still if no communication is made between the one and the other; but if a conducting substance is made to touch both the conductors, then the equilibrium is instantly restored with a flash and violence proportionate to the degree of electric action which has been excited. A few square feet of glass coated on both sides with tinfoil, and having electric action communicated to one of the coatings when the air is perfectly dry, produces, when the equilibrium is restored by establishing a communication between the conductors, a more intense though perfectly momentary action, than can be obtained by the greatest heat of ordinary furnaces.

From this we can easily see how the air together with the earth may act after the manner of the common machine, in exciting electric action; for we are to understand that as action is not substance, there is no generation of substance in a thunder storm, neither is there any original production of action (for that would be a work of creating, and not a phenomenon of the created world,) there is merely an awakening, or a putting into new circumstances, of that action which previously slumbered in its equilibrium, just as the action which projects a bullet previously slumbers in the gunpowder.

This action must, like every other action, be *greater* when the cause of it is more powerful, and *if* we are to find those places of the earth, where

the displays of lightning and thunder are the most majestic, we must seek for them in those places where the most extensive currents of the air, rush against each other with the utmost intensity, and where also the dry state of the earth and of the lower atmosphere, resist most powerfully the descent both of electric action and of humidity. The turns of the monsoons between the northern hemisphere and the southern are the times at which those displays are to be sought; and the places where we may expect to find those displays in the greatest splendour, are necessarily those where there are the greatest differences between the surfaces of the two hemispheres. If we look at the map of the world, and examine carefully the relative positions of sea and land in the tropical parts of it, we perceive that the west coast of India, Africa, on the northern shore of the Gulf of Guinea, the northern part of the continent of South America, and that part of the coast of North America, which lies along the Pacific, in a south east and north west direction, are the places which, from their geographical position, are most likely to receive the turning of the monsoons in all their fury. There are many minor places, and in some of these, in proportion to their extent, the violence must be greater than in the others, because of the peculiarity of their situations. But in those places which we have enumerated, it will be seen that the one hemisphere is for a great extent land, and the opposite hemisphere sea. Take India for instance: there is no sea to the northward of it till we come within fifteen degrees of the pole; and there the surface of the sea is covered with ice, in summer as well as in winter, with very

little intermission. There can, therefore, come no influence of the sea from the north to act in any effective manner upon India, or upon the country far to the north of it; and the Himalaya mountains on the north of India rise to such an elevation, that there is no communication between the air on the opposite sides of them, until the average height of two or three miles above the mean level of the sea is arrived at. India is thus cut off from atmospheric communication landward by the mountains; so that when the northern hemisphere is heated during our summer half year, and especially toward the end of that time, the air over it ascends as it were through a chimney; and the returning motion southward of the general atmospheric current bears it to the south. By this means the drought increases, until the atmospheric current is again directed northward; and when it arrives at the west coast of India it meets with powerful opposition from the dry surface, and the hot and dry air over it. There is another circumstance: the greater part of this coast of India consists of high mountains very near the sea; and these mountains present a still more formidable opposition to the lower strata of the air which is coming from the south, than the dry surface and air above the mountain tops, present to the upper strata. There is no land of any consequence between India and the south pole; and therefore the whole air of this monsoon is nearly saturated with moisture. It is air having its current originating over the sea, and passing into climates still warmer and warmer as it gets northward. Consequently, both its capacity for moisture, and the disposition of the moisture to supply that capacity, increase

as it proceeds along. It thus comes to the Indian shore fully charged with moisture; and it has to contend with an opposing state of the surface and the atmosphere already there, and also with the opposition of a ridge of mountains. To use a homely expression, its landing is opposed; and there is a fierce war of the elements, before the southern monsoon can so far get the better of opposition as to be enabled to refresh the country with that water which it brings.

For some days there is perfect calm in the atmosphere, and along with it a very intense degree of heat, so that exposure to the sun can hardly be endured even by the natives. At first the sky is perfectly clear, but it gradually acquires a yellowish and gloomy appearance, which in a short time deepens to reddish; and is often so close, that the sun appears through it shorn of his beams, as he does through a fog in this country. This is what may be considered as the contending currents being in the violence of their struggle, and when the one has not in any degree yielded to the other. But this doubtful strife does not last long, as both are under the controlling power of the sun, which leads on the current from the south, and beats back that from the north; but the state of the surface and the character of the coast enable the dry atmosphere to hold out to the very last extremity; and when the south begins to get the mastery, the whole atmosphere glares with lightning and peals with thunder, as if the whole artillery of the heavens were brought to the battle field. This usually begins in the earlier part of the night, and for a reason formerly explained, the dark comes on

there very soon after sun-set; and it continues gleaming and thundering; one moment as bright as day, and the next as black as midnight, until the equipoise of the atmosphere is completely destroyed; and then down comes the rain as if flood-gates were opened. Before morning the face of nature is completely changed: the soil is torn up, huge masses of stone are loosened, water courses dry only a few hours before, contain foaming rivers, and every rock pours down its cascade. Then away go plants, and trees of goodly size, and houses and lands, and every thing whithersoever the flood takes its course; and this continues sometimes for several days without intermission, more especially on those parts of the coast where the mountains are so lofty, that the whole of its fury must be spent between them and the sea. But though there is momentary devastation, there is no permanent destruction; for the seeds and roots of vegetables are carried along with the newly deposited soil which has been produced by the violence of the storm; so that by the time that the sun again has looked out for a few days, the country, which previously had been parched and plantless, is flourishing in all the greenness of a most vigorous growth.

In some other places, the violence is perhaps greater than this, and this appears to be more [illegible]se on the west coast of America, than any [illegible]e else. This might be expected from the [illegible]larity of the situation; for the current there [illegible]n the wide Pacific, with no land of any con-[illegible]ce to disturb it for thousands of miles; [illegible] the Indian ocean and also the South [illegible]

Atlantic are narrow in proportion, and both are situated between extensive and dry countries in the southern hemisphere.

There is one circumstance connected with the great violence with which the monsoon breaks on this lofty west coast of India, which is worth explaining, as illustrative of the production of rain upon mountains, when it is uninterrupted fair weather in the valleys between them. When the current of air sets against the side of the mountain, the lower part of it which meets the surface first, takes an oblique direction upward, and turns all the rest as high as the mountain top, so that the different strata incline there toward each other something in the form of a wedge. This occasions a mingling of strata at different densities and temperatures, and also a condensation by the pressure of the strata against each other; and both the circumstances lessen the capacity of the air for moisture, and the result is the formation of a cloud. This cloud is formed much nearer the hill top, than ordinary clouds are to the mean surface of the ground; and thus it is a rain-cloud at once, without those preparations which occur in gradual breaking of the weather, and generally also, though not always, without electric action. If indeed one part of the mountain or mountain-ridge rises in a peak high above the rest, with a passage for the air upon each side, the cloud may be seen formed like a flat cap on the top of it if it is not very high, and often like a bar across the middle height, if it is of greater elevation compared with the portion of the ridge on each side of it. To one at a distance those caps and bars have nearly the same appearance as air-clouds; and when one is at a

short distance from them, in the clear sunshine, for the sky is very often cloudless on such occasions, the cloud appears a light fog; but upon entering it, it is found to be a very peculiarly drenching sort of rain, which does not fall heavily, because the height from which it falls is trifling; but which wets one sooner to the skin than the more pelting rains of low and level places.

There are many other phenomena connected with the formation and the fall of rain; and that succession of states of the atmosphere to which we give the general name of the weather, the investigation of which is a very pleasing study. Indeed, as we have so much dependence on the weather for our individual comfort, for our intercourse with each other, and for that abundance with which the earth supplies us every season, and in some situations all the season over, we can hardly find in the volume of nature a page of more deep or more delightful interest. It has these further advantages, that in one or other of its details, it is constantly present with us, and that we must make ourselves acquainted with the natural history of the earth's surface, and the effects of the sun and the earth's motions, before we can study it usefully. We must, however, take leave of it, in order to cast a very hasty glance on

THE WATERS.

The powers of evaporation, and the descent of humidity from the atmosphere, in the state of rain or snow, or in that humidity which appears on the *surfaces* differently affected by heat from the air *over it*, and known by the name of dew, which are

continually going on at one part or another of the earth's surface, and generally over the greater part of it, at least in as far as evaporation is concerned, cause a perpetual circulation of a very considerable portion of water, from the earth through the atmosphere to the earth again; and this circulating portion which takes a journey through the air on one part of its circuit, may be considered as the portion which ministers to the economy of the land, and of land plants and land animals. This, however, is a very limited portion as compared with the whole quantity of water which is accumulated as oceans, and as seas, in the deepest hollows or basins, which occur upon the earth's surface.

To attempt an accurate estimate of the quantity of water upon the earth would be in vain, because it is too great, and its distribution is too irregular for human measurement. When, however, we cast our eyes upon a representation of the earth, in an accurate map or globe, we can at once see, that water must be one of the most important elements in its economy, especially in that surface economy, in which the air of the atmosphere, and the influence of the sun are so much concerned. According to the most careful estimates which have been made (but these are far from accurate), the oceans and seas occupy about seven-tenths, or more than two-thirds of the entire surface of the earth. If we suppose that the whole surface of the earth is two hundred millions of square miles, and this is not very far from the truth, then the land will occupy sixty millions, and the sea (for we may take that as the general name of the whole oceanic waters, whatever may be their specific distinctions), will make one hundred and forty millions. This estimate

of the surface of the sea, gives us no information whatever as to the absolute quantity of water which it contains; because we do not know the depth. It is probable that the bottom of the sea is, in some places at least, nearly as irregular as the surface of the land; though, as the irregularities of the land appear in their ultimate formations, to have taken their forms opposed by the resistance of the atmospheric air only, which on the average is equal to about a depth of only thirty-two feet of water, and as some parts of the sea have been found, by actual sounding with a deep-sea line, to exceed a mile and a quarter, and others, no doubt, much greater than this, any formation taking its shape under such enormous pressure, must be more uniform than that which takes its ultimate shape under the comparatively small pressure of the atmosphere only. Some theorists, reasoning from the oscillation of sea water in the tides, have allowed a mean depth of between two and three miles to the whole of the seas; and this would give a vast quantity of water, not less than a trillion and a half of tons, which is a number altogether beyond the powers of the human understanding. A trillion is expressed arithmetically, by 1 with eighteen 0's after it, and any one who chooses to write this, and substitute 5 for the first 0, will see how very formidable a number the tons of water in the sea, according to this estimate is, when expressed in the abridged notation of arithmetic. Such estimates as this, serve no other purpose, however, than that of exciting our astonishment, and enlarging our conception of created things and their Creator; because the oscillations of the sea are affected by so many causes which are known, and may be affected by so many others

of which we are ignorant, that the application is a mere guess.

There is one difference between water as it exists in the sea, and as it is found in that circulation which refreshes the land, that never fails to strike even the most careless observer. The circulating water as it is raised in vapour, and as it descends in rain, is perfectly pure; and if it becomes mixed with foreign matters, in springs, in pits, or in the courses of rivers, we can readily understand that the impurities are derived from those portions of the solid matter of the land, over or through which it has passed, from the time of its being pure water in the atmosphere, to that of our observing it in its mixed state. The sea, on the other hand, contains no pure water except that which it has immediately received from the land; and which has not had time to mix with the general volume of its waters. It is true that the water which the sea contains, considered in itself, does not differ in its composition, or the proportion of its component parts, from that of any other water; but it holds in solution a great number of other substances, which taken altogether, amount to rather more than three and three quarters per cent of its whole weight. Owing to different causes, however, the quantity of those ingredients is not the same in all parts of the sea. We can easily understand why this should be the case; for there must be the smallest quantity of these ingredients in those parts of the sea which are constantly receiving the largest supply of fresh water from the land, and giving off the least quantity of pure water by evaporation. On the other hand, there must be the greatest proportion of those ingredients where the supply of fresh water from

the land is least, and the drain of pure water by evaporation greatest. This is evident, because, though we were to suppose that the whole waters of the ocean circulated round the globe, and mingled together, yet we could not help seeing that this circulation must be very slow, as compared with those operations which tend to change the quality of the water in different latitudes.

Reference to a good globe, or a good map of the world, which is preferable, because it shows us the whole surface at one view, is necessary, in order to form even a moderately correct judgment upon this point. Upon making this reference, it will be found, that there is very little water discharged by rivers into the sea, on the south side of the equator, compared to what is discharged into it, on the north side; and that the quantity of sea, south of the equator, is far greater than the quantity north. As the heat of the sun from the greater quantity of land that there is in the northern hemisphere than in the southern, must have a greater effect upon that hemisphere, it is probable, that from equal surfaces of the sea, there may be as much evaporation in the northern hemisphere, as in the southern; but still the extent of surface in the southern hemisphere is so much greater, that the whole evaporation from it, must exceed the whole evaporation from the surface in the north. The inference from this is, that the seas of the southern hemisphere should be salter (for salt is the general name given to all the substances which are intimately mixed with the waters of the sea), than the seas of the northern hemisphere, and actual examination shows that this is the fact.

For reasons nearly similar, the polar seas ought to contain less saline matter than the equatorial seas; and we find this also to be the case. Of the economy of the southern polar sea we know little or nothing; because the surface of the earth there has been seen only at a few points. Consequently we cannot tell whether it is sea or land, or indeed, any thing about it, farther than that as there is uninterrupted ocean completely round the globe, for a considerable distance in those latitudes, we may conclude that its action, or repose, whichever of the two it may be, must be more confined to itself, and separated from the economy of the rest of the globe than that of the northern polar sea. We are more familiar with the northern one, because great part of the sea there has been resorted to by the whale-fishers, and the greater part of the sea, and much of the land also, has been explored by competent men of different nations who have done so for the express purpose of making discoveries. From this evidence, which though not yet quite complete, is both complete and satisfactory as far as it goes, we know that the northern polar lands are for a great part of the year covered with snow, and the seas with ice, having snow upon the top of it. The snow descending from the atmosphere, of course consists of pure water without any saline ingredients; and though the pores or openings which are in the mass of the sea ice, may contain salt, there is none in the crystals of the ice; because the saline ingredients separate from the water in the act of freezing; and as salt water is heavier than fresh water, and fresh water heavier than ice, from ice expanding a little in the act of freezing, the salt naturally descends, and in most instances

These salts are all very active substances; and the parts of which they are compounded are in general more so. The soda, both in the common salt and the glauber salt, is the same soda which we have already described in the preceding chapter; and so are the magnesia and the lime, also, the very same. The active principle which is combined with the metallic oxides in the muriate, is chlorine; the same substance to which we have already alluded, as being remarkable for its bleaching properties, and for destroying every sort of pestilent vapour. Now it is a remarkable coincidence that the very same substance which we find most efficient in discharging colours, and in removing infectious matter, should be diffused every where through the waters of the sea; nor is it less remarkable that soda, which is even more abundant in sea water, is the most efficacious substance that we have for washing without discharging colour; and it is the material which, combined with oil, makes the best of all soap, which is merely soda blunted a little in its action by the oil, as the oil alone would stain and not cleanse.

When we reflect upon this, we perceive that the saline ingredients of the sea, instead of soiling the water, convert it into one mighty basin in which all the impurities of working nature are washed away; and the materials which are constantly carried down and deposited in the sea, are stored up there, pure, free from corruption, and ready for the formation of lands perfectly new, whenever the law of the world's government shall render it necessary. This is a striking proof of design in the adaptation of the sea and land to each other; and mighty as the sea is in its majesty, and useful

as it is as at once the barrier which divides, and the highway which unites, the different nations of the world, its importance rises many-fold when we contemplate it working on the grand scale, and see the important service—the countless myriads of services—which it performs to the land. All the waters which the lakes, rivers, and moist surfaces and substances upon the land send up to the atmosphere, by the process of evaporation, are hardly as a drop in the bucket, compared to what is sent up by the sea. Then the surface of the sea is uniform, and the winds sweep freely across it for thousands of miles, bearing on their wings the superfluity of one place to relieve the necessity of another, without any of those little interruptions and local disturbances which hinder the portions of the atmosphere over different parts of an extent of land, from communicating with, and relieving, each other. Examine the seasonal history of any land, even though it is not very extensive, and you shall find that while one part of it is burned up with drought, another part is deluged with an excess of rain; and all this because the diversified surface of the land intercepts the free communication between portion and portion of the atmosphere. But go to the shores of the sea, let it be as extended as it may, and you shall find that its bounty is distributed everywhere. No doubt there are barren shores in many parts of the world, as well as barren tracts in the interior of countries; but in every case of this kind, the fault (if we can call anything in nature a fault) is in the land, and not in the sea. In its own waters the sea knows no barrenness; and it dispenses its bounty freely to all around, though the rain of course falls unprofitably

upon the naked rock, and the dew distils in vain upon the thirsty sand. Yet even these places are not without their use in the economy of nature; for by repelling from themselves that bounty of the sea which, from their nature, they could turn to no account, they concentrate the same bounty upon those places which are fitted by nature for turning it to the best advantage. In this point of view, we would require to pause ere we pronounced sentence of unprofitableness upon Sahara itself; for it is highly probable that but for its dry and sandy surface, so sensitive as it is to the action of the sun, the vine might not clothe the Italian hills, or the harvest wave yellow on the fields of England.

But to return to the composition of this wonderful ocean, or, more correctly to express it, this ocean of wonders, it is very remarkable, that with the exception of magnesia and lime—which latter is in an especial manner the animal earth, and essentially the formation of the bone, the shell, and the crust,—there is not one of the earths found distributed, and held in solution by the waters of the sea; and it is equally remarkable that this earth, which is essential to the purposes of life in the ocean waters, should be chained down there by one of the most energetic principles in nature, and one which will purify it at the same time that it renders it up—namely, chlorine.

Another very active principle, or rather substance, which is found in the sea, is iodine. It is not found in the sea water, but in the plants which grow in that water, and which plants usually contain soda in much greater quantity than land *plants* contain potass. When obtained in a separate *state*, iodine is solid, of a greyish black colour,

and has the lustre of a metal. It is an exceedingly active substance, and in even small quantities it is a deadly poison. When in the state of vapour, it is of a violet colour, and hence the name. Its uses in the economy of nature or in the arts have not been investigated to sufficient extent for enabling us to state them with precision; but its active nature renders it probable that it may hereafter be turned to considerable use. I thas been used in medicine, but it requires to be used with the greatest caution. This substance is not found in any land plant, and we do not know that those plants of the salt marshes and shores of the sea, which, like marine plants, have their alkaline matter soda, and not potass, as in land plants, have been examined with the view of ascertaining whether it enters into their composition or not. It is, however, contained in some minerals, but those are so rare, and it occurs in no small quantities, that its occurrence in them does not establish any connexion between its existence in the sea and on the land.

When all those foreign ingredients which are mixed with the ocean waters have been removed, the remainder consists of pure water as limpid as that which falls from the clouds. This, which till times comparatively recent was regarded as one of the four elements of which all material things are composed, is a compound, a chemical one, and one the parts of which are held together by a very powerful attraction. This attraction does not relate to the consistency of the water, regarded as a mass, for it is the same whether the mass of water is in the state of ice or liquid, or dissipated in viewless vapour. It relates to the union of *those constituent* parts, oxygen and hydrogen, of

the first of which, considered as a gas, it contains one measure; and it contains two measures, or twice as much in bulk, of the second, or hydrogen, that is, on the supposition that both gases are at the same temperature, and subjected to the same pressure. These gases may be obtained by well known and easily performed operations, from substances in which they are contained; as, for example, hydrogen may be procured by the decomposition of water by means of iron in a state of minute division, and sulphuric acid; and oxygen may be obtained by exposing the black oxide of manganese to a strong heat. We shall not detail the particulars of either process; because our object is not to teach chemistry, but to state general principles, and merely to refer to these modes of production in order to show that water has been obtained by uniting its elements; and, in order to do this, it is necessary to procure those elements in a state of purity. If we take one bulk of pure oxygen gas, and two bulks of pure hydrogen gas, and put them into a vessel from which every other substance has previously been removed with the utmost care, that vessel contains the elements of a certain quantity of water. No mechanical process, and no action of common fires with which we are acquainted, can, however, combine those elements into liquid water. In order to do this, we must have recourse to a more powerful species of action, and pass an electric spark through the mixture of gases, from one piece of metal to another, something in the same way as we formerly explained of a glass jar coated with metal inside and out. When the electric spark is passed through the mixture, this mixture instantly passes into liquid water, but the weight

of the vessel and its contents is not in the least altered, which leaves not the smallest doubt that the water which is produced is composed of the whole of the mixed gases, and of nothing besides. As water is of so much greater specific gravity than either of its constituent parts, it follows, of course, that the volume of water obtained must be very small in respect to that of the gases. From the experiments it appears that the water is only about a two-thousandth part of the bulk of the gases which form it.

We have already had occasion to mention that the general action of heat is to expand substances; and that the portion of this heat which is requisite for maintaining the state of the substance, is not discernible by our senses or our instruments, but is latent or hidden. This latent action of heat, though imperceptible by us, is not destroyed; for its full energy is exerted in maintaining the state of the substance, and therefore, though its working is inscrutable to us, it works incessantly. There is evidence of this in the fact that the instant the heat is withdrawn, the substance returns from the state in which that heat maintained it; and if any of two substances which are to enter into a chemical combination, is under the influence of a powerful latent action of this kind, the whole must be brought up to a corresponding temperature before the union takes place, though this varies with the greater or less disposition which substances have to unite with each other. The heat of a common fire would merely expand the mixed gases, and the expansion might in time burst the containing vessel without the least union; but the heat of the electric *spark is far* more intense than that of any common

fire, and its action is instantaneous, so that the gases are united before they have time to expand.

But though the application of the heat of common combustion will not explode those gases so as to cause them to combine, it will do so if they are mixed with, or exposed to, common atmospheric air. That air is, in respect of combination, or the combination of substances by common fires, a diluted oxygen gas intimately mixed with nitrogen; and this causes the mixture of gases which form water to enter into combination, though they still combine with the same intensity of heat and brilliancy of light as when they are combined by the electric spark. The operation can, in this case, be made continuous by furnishing a supply of the mixed gases through a very small aperture; and this is the mode of proceeding in what is called the "oxy-hydrogen" lamp, which gives so intense a light as to answer instead of the direct light of the sun in using the solar microscope. Common gas lights, which are now so much used, consist in part of this operation, though in them, even when the gas is as pure as human skill can render it, there is always a third element which, though it increases the heat of the combustion, diminishes the brilliancy of the light. This substance is carbon, which, as we have said, is nearly pure in diamond, and which forms part of all animal and vegetable and of most mineral substances.

The decomposition of water by the direct separation of its parts, without the application of any substance which shall abstract the one of them and leave the other, requires an equal application of heat; and therefore this decomposition may be one of the means by which many of those powerful

actions of heat, which display themselves in the earth and in the bed of the sea, are carried on.

There is a comparison of water with atmospheric air which is not uninstructive, as showing how well the structure of each of them is adapted to the office it has to perform in nature. Each of them consists, in by far the greater part of its volume, of a compound of two principal ingredients, and each of them holds in solution, and circulates round the globe with its own circulation several other substances; but the air is comparatively free, and it is rare and light in its substance. Its constituent parts are accordingly simply mixed together, and the compound possesses the properties of both, though each is in so far concealed by its mixture with the other. The air, by extending far above the most elevated parts of the earth, being so free in its motions, so rare in its texture, and yet having considerable weight in the whole column of it over any given spot, reaches, by its own action, and without the intervention of any other agent, every point of every object where its presence is necessary, or where one of its constituent parts, or any of the substances which it holds in solution, is required for the performance of any operation, or the necessities of any creature. It is in itself a messenger and a carrier, but in its circulations it does not require to be carried by any other substance; and therefore there is no necessity that its constituent parts should be powerfully united.

With water again the case is very different. Its weight as a substance makes it always sink down to the lowest place that it can reach; and with the exception of that disposition which it has to rise in *vapour*, and which, as we formerly said, is regulated

by the pressure of the air, it has no tendency to ascend again from the lower places so as to reach the higher. Its disposition to evaporate, if not regulated by the atmosphere, would act simply as an antagonist power to its gravitation, and the vapour would pass away from the earth in straight lines directed from the earth's centre. To what extent of its quantity it might thus ascend, and to what height—that is, what distance—from the earth's surface it might go, without the atmospheric restraint, we have no means of ascertaining, because it is impossible to make the experiment in the absence of the atmosphere. But, from all that we know of the circumstances, the gravitation of water must diminish, and its tendency to evaporate increase, as it is further removed from the earth's centre; therefore the rational conclusion is that, if the atmosphere did not restrain it, it would always move the faster the farther that it went; and to this there is no end but the supposition that it would be entirely dissipated through the regions of space; and that if there were no atmosphere surrounding the earth there could be no water in a free state upon its surface. But whether it would be thus dissipated or not, it is perfectly evident that no part of it could descend upon the dry land; and thus, whether it would be dissipated or remain in connexion with the earth, it would be useless for every purpose of life were it not for the atmosphere.

There are no doubt many operations in nature in which water is decomposed; and where the one or the other enters into combination with some substance, while the remaining one either combines with another substance, or passes off freely in the state of gas. When organic substances putrify in

stagnant water, the oxygen of the water generally combines with some part of them, as for example with their carbon, to form carbonic acid. In this case the hydrogen of the water is separated; and escapes as a gas, either pure, or combined with some of their more volatile parts, such as sulphur or phosphorus. Those combinations with hydrogen are all specifically lighter than common atmospheric air, so that they ascend; but most, if not all, of them have an offensive odour, and are poisonous; and this is the reason why the vapour which arises from stagnant water, in which organic matter is putrifying, is so offensive and so pestilent. The combinations of the oxygen of the water with carbon is by no means so offensive; for though the carbonic acid gas which this process forms is poison to the lungs of animals, it is in other respects essential to the growth and nourishment both of plants and of animals. It is also so much heavier than atmospheric air, that it runs into the hollows like water; and though it stagnates in a hollow, it is perfectly harmless, unless it is so deep that it reaches the breathing apparatus of any animal which attempts to pass through it.

There are some remarkable instances of this stagnation of carbonic acid gas at peculiar places of the earth's surface. It is usually given out in countries where there is volcanic combustion going on under the ground, whether there happens to be any surface volcano or not. The *Grotto del Cani*, or cave of dogs in Italy, is one instance. The interior of the floor of this cave is lower than the entrance, and the shallow basin thus formed is continually filled with carbonic acid gas, which however never rises above the level of the entrance,

because the gas flows out there upon the same principle as water. The basin is deeper than the height of a dog, but not so deep as the height of a man ; and so a man man may walk into the cave, and remain there with perfect impunity, if he does not bow down too low, whereas if a dog ventures into the basin he instantly falls dead.

The poison valley of Java is a more remarkable instance of this kind. It is a basin of an oval form, about half a mile in circumference, and thirty feet in depth. The grounds around it emit a very offensive odour, consisting probably of some of those compounds of hydrogen which have been mentioned; but there is no offensive smell as one descends the upper part of the banks of the valley. A little way down, however, vegetation ceases at a perfectly level line all the way round; and below this there is a spectacle of the most direful desolation. There is not a plant, or a vestige of one; and the sides are strewed with the bones of animals—human beings, tigers, deer, and many other animals, together with various birds, all lying white and bleaching. To enter this valley, for an instant, is fatal; and any creature that enters it, though it is on the wing, if it descends low enough, leaves its bones as a memorial; and there the preyer and the prey are laid in one common death.

But besides the combination of the constituent parts of water with other substances, water itself, which differs greatly from both of them in its properties, is in general demand; plants and animals require a great deal of it; and through all nature and in all art upon the surface of the earth, it is one of the most generally useful of substances. Nor is it less useful in those mineral operations

which go on in the earth; for there is hardly a crystal, and very few compound rocks into which water does not enter; and no kind of soil that we are acquainted with, could long remain fit for the production of vegetables, unless mixed with a certain proportion of water; for without this, the clayey soils would become as hard as stone, and the less consistent ones would be converted into dust, and carried off by the winds.

Thus we see, that in proportion as we extend the range of our contemplation in the works of nature, the wisdom, power, and goodness of the Creator are more forcibly demonstrated. We admire the structure of a single plant, or the action of a single animal, and we find in them a wisdom of design and a perfection of execution, rising, not merely in degree, but in kind, above all that man can plan and execute; and yet, this superior working addresses itself so finely and so forcibly to the human understanding, that the productions of nature are in all cases the models of art, whether the thing made is to please the eye or assist the hand; we admire these, and we do so justly; but when we contemplate those more extended and universally operating parts of the system of the earth, and find, that though each of them has countless thousands of operations to perform, it is equally well adapted for the performance of each of them, we cannot fail in being lost in astonishment, and overwhelmed with the delightful feeling that the Almighty has set this fair world before us, and endowed us with powers fitted for its contemplation.

CHAPTER XI.

THE HEAVENLY BODIES.

If the study of the more extensive substances, and the more general and powerful operations which take place in the earth, are calculated to give expansion to the mind of man, and at once to arouse his energies in the way of well doing, and call forth his spirit in reverential adoration of his God, much more are the glories of the Heavens calculated to impress upon him the same feelings with tenfold sublimity and force. The general notion that we form of that universe which comprises all those radiant portions of matter which beam by day, and shine or sparkle by night, what is it? Where shall we mark its beginning? Where shall we imagine its ending? In the short career of our small planet round its moderate orbit, we shift our position mightily in space; for if we take the point when we are mid-summer, and that where we are at mid-winter, from the one of which to the other we and all about us pass in six short months, and that by a longer path than the direct distance, if we take these two points and compare them with the rate of our own motion along the earth's surface, even when we are in the vigour of life, the result of the comparison is wonderful. Suppose a man could set out from the one of these points, and proceed to the other in a straight line, and keep marching day and night at the rate of four miles an hour, it would take him more than one hundred and twenty thousand years to perform the journey. This is a vast distance, and yet in the universe,

even in the sphere of those heavenly bodies of which we have some knowledge as masses of matter, it is hardly worth counting; for one of the planets is two hundred times farther distant from the sun than we are; and therefore the distance between the points where it is situated at the mid-summer and mid-winter of each year, must be four hundred times as great as ours. Four hundred times, according to our mode of reckoning, are a good many; and this which is four hundred times one hundred and ninety millions of miles, is a goodly distance. But still this distance is a mere nothing as compared with the universe,—that mighty work, of which our earth and all its inhabitants form a comparatively smaller part than the final particle into which water can be divided by the most powerful evaporation of the upper air, is of the whole volume of the ocean.

It is true, that this distance to which we have alluded, which is the distance of the planet Uranus from the sun counted twice over, and which in round numbers may be called three thousand five hundred millions of miles, is the extreme limit of our knowledge of positive distance, as far as the power of instruments, and the industry and skill of observers have hitherto gone. What more belonging to the system of our sun may be beyond this to reward future observation, it is impossible to say; but even this is a distance of which we can form no accurate conception.

It is true that this is not the limit of vision, and that hough, if it is simply out of contact with us, mat r as existent does not reveal itself to us so as to g e us any knowledge of its existence; yet the acti of light can beckon us onward, and show us

the glories of the Almighty's work, at distances compared with which this limit of our measurement is not a hair's breadth.

By means of the best instruments, we can measure the distance of an object from us, if their distance is not less than two hundred thousand times the breadth of the object; and conversely, if we view from the two extremities of the breadth of the object we can find the point of the former observation, if its distance is not greater than two hundred thousand times the breadth of the object. We can observe a star as from the point where we are at mid-summer, and also from that where we are at mid-winter; and if we consider their distance as the breadth of our object, we shall be able to find the distance of the star from the earth at each of those two times, if it is not more than two hundred thousand times their distance. For very remote distances this would not be very accurate; but, still, some result or other not exceedingly wide of the truth, would be obtained. When, however, we attempt practically to do this, we find that the hundred and ninety millions of miles between our two points does not tell at all upon the distance of the star, and cannot be regarded as an assignable fraction of it. Therefore, all the conclusion to which we can come is, that the distance of the brightest, and as we naturally conclude the nearest, star in the heavens must exceed thirty six billions of miles, for which the following is the expression in numbers:

36,000,000,000,000.

This number, vast as it is, and irreconcilable *with any* of our common notions of numbers, is *yet not the* distance of the nearest star, but a dis-

tance beyond which that star must be situated; and the real distance may, for aught we know, be equal to many times, or many thousand times, this expression. This much for the nearest of the stars; and as all that we can tell about the remoteness of the star from us is negative, or that it is not within a certain distance, so all that we can tell about the nature of the star must also be negative, a judgment as to what they are not, and not what they are.

Those who are familiar with the heavens distinguish stars by different *magnitudes*, from the first down to the sixth or seventh to the naked eye of one whose power of vision is good; and from that down to about the sixteenth by the help of the very best telescopes. When we speak of the magnitude of a star, however, we must be on our guard least we should deceive ourselves. If we cannot measure the distance of any body, that is, if its distance is beyond the limits of our mensuration, it is impossible that we can determine its magnitude, or even come to the conclusion that it has any magnitude at all, farther than the inference which we draw from the light revealing it to our sense of vision. This, however, of itself tells us nothing about magnitude, or whether there is any substantive magnitude in the case; for light is an attribute of a certain intensity and modification of action; and what it really tells us concerns action, and not substance, unless in the case of light proceeding from one body, and being reflected from other bodies, in the same way as the light of the sun reveals to us the different objects which we observe upon the surface of the earth.

When we endeavour to obtain a knowledge of

the system of the heavens, in that spirit of reason which alone is consistent with true philosophy, it is of the greatest importance to have correct notions on this same subject of magnitude as connected with sight, otherwise we are in danger of falling into very fatal errors.

There is really no such thing as a visible magnitude; for the notion of magnitude is a compound and mental one, and not originally attainable by the exercise of any one sense. Light is the only agent which can affect the eye, and produce the original sensation of vision; and as differently modified surfaces affect the light differently, so as to make the objects to which they belong of different colours, it may be said that we see nothing but colours; and that the colour which we see, without an after process of the mind, gives us no knowledge whatever, either of form or of magnitude. There is no better proof of this than that which we have in the case of a well-painted picture. The canvas on which the picture is painted is generally speaking a level surface; but the skill of the painter not only gives body and relief to the different parts of the composition; but can give us the impression that the picture really extends for a long distance backwards into space; and this, in some instances, so true to nature, that it is difficult to bring one's self to believe that it is a mere device of art, and not a natural reality.

It is necessary for us to bear in mind the different effects of light upon the objects which it reveals to us in all cases of observation, but it is more especially so in our observation of the heavenly bodies; for the distances at which they are placed from us, may be said all to exceed our common judgment

of distance by sight; and therefore the whole heavens appear to us as one hollow sphere, or rather portion of a sphere, resting upon the earth at the horizon which bounds our view. It is true that as we are able by the naked eye to observe differences of colour in the moon which have permanent shapes, we naturally conclude that the moon is nearer to us than the sky in which it appears, and the brightness of the sun leads us to a similar conclusion with regard to that luminary; but still the conclusions we come to in this respect are exceedingly vague, and they furnish us with no notions whatever of their real distances. These circumstances render the science of the heavens very different in reality from what it is in appearance; and thus, though in its nature it is the simplest of all sciences, it is one of which no single individual of the human race could acquire for himself even the most elementary knowledge. The proofs of the real state of things concerning the celestial bodies are exceedingly clear and convincing, and they are not very difficult to be arrived at. But there is none of them on the mere surface, or open to a common observer, as is the case with ordinary objects upon the earth. We can see all classes of these bodies in their daily rising and setting, or the apparent circular course of those which revolve round without setting; and if we are attentive, we can further observe the shiftings of the nocturnal heavens gradually westward at the same hour on every successive night. We can still more easily observe the monthly changes of the moon; and when an eclipse of the sun happens at new moon, we can thence conclude *that the moon* is nearer to us than the sun.

is; neither does it require much reflection upon the connexion between the changes of the illuminated portion of the moon, and its angular position with regard to the sun, to find out that the moon does not shine by its own light, but merely by reflecting the light of the sun. Besides this, we find that there are certain stars more steady—that is, less twinkling in their light than the greater number of these luminaries, but which shift their places, some more rapidly, and others more slowly; and that they appear to shift them sometimes in one direction, and sometimes in the opposite one. The beautiful planet Venus, for example, which is the morning and evening star by way of eminence, is on the west side of the sun when a morning star, and on the east side when an evening one; but it never deviates to any very great distance; and the time between its being at the greatest distance, or elongation as it is called, eastward or westward, to its returning to the same again, is about five hundred and eighty-four days. Mercury (which is so near the sun as rarely to be seen by the naked eye) takes only about one hundred and sixteen days; and there are other stars which are still more devious in their courses over the heavens. These wanderers are called planets, because they appear to be discursive over the surface of the heavens, while the great body of the stars are subject to but little change of place in respect of each other.

These motions, which are the chief of those that the unassisted eye can perceive in the heavens, are quite incompatible with any general motion of *celestial* space round the earth which we inhabit as *a centre*; and taking them altogether they are *quite incompatible* with motion round any single

centre, wherever we may suppose that centre to be placed. The moon for example, between one new moon and another, evidently revolves round the earth, but not round the sun; because, even when it is in the same part of the heavens as the sun is, it is on the same side of the sun as the earth is. Mercury and Venus again evidently revolve round the sun and not round the earth; for when either of them comes to exactly the same part of the heavens as the sun, seen from the earth, it passes over the body or disc of the sun like a round dark spot, producing what is called a transit or passing over; and there are other cases in which it is observed to pass behind the sun, or sustain what is called an occultation, after which it reappears from behind the other edge, or limb as it is called of the luminary.

Both of these planets, therefore, must revolve round the sun, but none of them can revolve round the earth, otherwise it would sometimes be on the side of the earth opposite to the sun, just as is the case with the moon.

There are several others of those starry bodies or planets, some of them visible to the naked eye, and others not, which evidently revolve round both the sun and the earth; because they are sometimes found in the same part of the heavens with the sun, and sometimes in the part exactly opposite; but when they are in the first of their positions, they never transit, or pass over the disc of the sun, but always suffer occultation when they are sufficiently near. These circumstances could not take place, unless those planets revolved round the sun and the earth also; and as, like the moon, they appear all to be dependent upon the sun for their light, and

have little influence upon the earth, while the earth appears to have just as little upon them, it would be contrary to the whole plan of created things, in which nothing is useless, or not perfectly adapted to its use, to consider them as having much reference to the earth in any respect whatever. Common observation would therefore lead us to conclude that these last mentioned planets revolve round the sun at a greater distance than the earth is; while the first mentioned planets also revolve round the sun, but at a nearer distance than the earth.

All the bodies which thus revolve about the sun, compose what is called the solar system. When they revolve round the sun only, they are called primary planets; and when they revolve round a primary planet, they are called satellites, or moons. The planetary bodies, including the earth, are ten primaries, but it is not known how many more may be discovered; for of the ten with which we are acquainted, only four, Venus, Mars, Jupiter, and Saturn, are very conspicuous to the naked eye. Mercury, when it can be seen, which is about the time of its greatest elongation, is also a large and bright star; but the remotest one from the sun, Uranus, though a large body, is rarely seen by the naked eye; and four others, Ceres, Pallas, Vesta, and Juno, are never seen but by the help of a telescope; and it is only since telescopes were brought to great perfection, that the five last mentioned have been known to astronomers.

No machine, drawing, description, or other human contrivance, can convey to the mind anything like an adequate notion of the splendour of the solar system; but the following passage from

Sir John Herschel's beautiful treatise on astronomy is perhaps the best that ever was attempted in words:—"Choose any well-levelled field or bowling-green; on it place a globe two feet in diameter; this will represent the sun; Mercury will be represented by a grain of mustard seed, on the circumference of a circle two hundred and eighty-four feet in diameter; the earth, also, a pea, on a circle of four hundred and thirty feet; Mars, a rather large pin's head, on a circle of six hundred and fifty-four feet; Juno, Ceres, Vesta, and Pallas, grains of sand, in orbits of from one thousand to one thousand two hundred feet; Jupiter, a moderate-sized orange, in a circle of nearly half a mile across; Saturn, a small orange, on a circle of four-fifths of a mile; and Uranus, a full-sized cherry, or small plum, upon the circumference of a circle more than a mile and a half in diameter. As to getting correct notions on this subject by drawing circles on paper, it is out of the question. To imitate the motions of the planets in the above-mentioned orbits, Mercury must describe its own diameter in forty-one seconds; Venus in four minutes fourteen seconds; the Earth in seven minutes; Mars in four minutes forty-eight seconds; Jupiter in two hours fifty-six minutes; Saturn in three hours thirteen minutes; and Uranus in two hours sixteen minutes."

The above description is, as nearly as possible, a resemblance to the proportions of the system, so far as the average sizes, distances, and times of revolution of the different planets are concerned; and to have some general idea of the working of the system, and the means by which so many bodies, so large in size, placed so far apart from each other, are

sustained, it is necessary to attend only to the balancing of one planet in its orbit or path; because the law which applies to them is uniform in principle, though different in intensity in the different planets, and in the same planet in the different parts of its orbit.

The sustaining principle is the very same which we meet with in all mechanical nature, namely, the attraction of gravitation, to which allusion has been made at some length in a former chapter of this volume. Gravitation is found to be common to all matter in so far as observation has been extended; and there is every reason to believe that it is perfectly universal, and the best and only absolute evidence of the presence of matter. The law of its operation is also an exceedingly simple law, though, as we observe it, it seems complicated from the influence which different portions of matter have upon each other. Any portion of matter, heavier than its own bulk of atmospheric air, which we can raise from the surface of the earth at any place, falls down to the earth, when unsupported, in virtue of this law of gravitation. The earth also is so large, and its gravitation in consequence so powerful, that any portion of matter which we can raise by artificial means must yield to the gravitating influence of the earth, unless it is held together by some attraction of cohesion. Thus a stone, a piece of timber, or any other hard solid, has cohesion enough to retain its shape, but water disperses itself along the surface, and obeys the law of gravitation to the earth, by descending from higher places to lower, when *not* restrained by a sufficient obstacle.

As gravitation is the test of the presence of *matter*, we might at once infer that it is the mea-

sure, and the only exact measure, of the quantity of matter. Such is found by experience, in every instance to which experience can apply, to be actually the case; and therefore we have one branch of the general law of gravitation expressible in these terms:—Every portion of matter, be it large or be it small, has a constant tendency, in virtue of the law of universal gravitation, to draw towards it every other piece, in the exact proportion of the quantity of matter which it contains.

Suppose then that two pieces of matter perfectly undisturbed by any others, and thus left quite free to the action of this branch of the law of gravitation, it is quite evident that each of them would attract or draw towards it the other with exactly the same force; and that therefore they would come into contact exactly mid-way between the situations from which they began to move. If, however, the one contained more matter than the other, it would be attracted or drawn by a less power than that by which it attracted or drew the other. Thus, for instance, a piece of matter containing a double quantity would exert a double attractive power, and two such bodies would meet each other at one-third of their distance from the larger one, and two-thirds from the smaller one. According as these relative quantities of matter vary, the proportional parts of the original distance, over which, respectively, they moved, would also vary; and any piece of matter which we can, by artificial means, raise from the surface of the earth, is so exceedingly small in comparison with the mass of the earth, that though the motion of the piece of matter toward the earth is quite perceptible, the *motion of the earth* towards the piece of matter is

not at all perceived. The largest mountain, if it could be flung into the air, would be far less in proportion to the earth than the lightest thistle-down in proportion to the mountain; and therefore, though the mountain, if projected to a sufficient height, would fall to the earth with great rapidity and violence, the approach of the earth toward the mountain would not be sensible to the very nicest observation. But though the motion of a body, say a million times another, would be only one millionth part of the distance in space passed over by the law of gravitation as that of the other, both motions would be performed in exactly the same time; and consequently the speed or velocity with which each moved would be in proportion to the distance that it passed over.

It follows immediately from this, that if there is any system of bodies, or masses of matter moving in free space, the largest of them, that is, the one which contains the greatest quantity of matter, must be the most stable, that is, have the least motion; and that no larger one could by possibility revolve round a smaller. We have already said that it appears from observation that the moon revolves round the earth, and that the earth, and all the other planets composing the solar system, revolve round the sun. It follows, by necessary consequence, that the earth is a larger body, or contains a greater quantity of matter than the moon does, and that the sun is a larger body, or contains a greater quantity of matter than any of the attendant planets—greater indeed than all of them taken together; for if this were not the case, *as they* all move at different distances, and with *different* velocities according to those distances, it

might so happen that their gravitating influences would be united, which would destroy the governing influence of the sun, and the whole system would go into confusion.

Our limits do not permit us to enter into a detail of the particulars; but it is sufficient to say that the sun is so much larger in quantity of matter than the planets, that if the whole of these were placed in the same straight line, and their gravitating influence thus united, the sun would still outweigh the whole in the balance of gravitation, so that the centre of gravity, a point to which the matter of the whole would move if free to obey the simple law of gravitation, as dependent on quantity of matter alone, would still be within the body of the sun.

This simple branch of the law of gravitation is, therefore, the principle of stability in the system; and as it is a passive force, tending to union and rest, an active force of equal intensity is required in order to keep up the motion of the system.

Before, however, we enter upon the explanation of this, it may be necessary shortly to mention how the tendency of gravitating bodies towards each other varies with the distances which they are from each other. Now, gravitation always tends, or is directed toward a certain point within every attracting body, which point is called its centre of gravity, and, if this centre of gravity is supported, the whole mass of the body is supported. This follows immediately from the fact of gravitation holding the different parts of the same body or mass of matter in union with each other; but it is also *proved by* experience, in every case to which *observation or* experiment can be applied, for we

can determine where the centre of gravity in any detached piece of matter near the earth is situated; and if this centre of gravity is supported the body does not fall, whereas, if it is not, the body falls on that side in which the centre of gravity is situated. This is readily understood by adverting to the common beam and scales, which are used in weighing. If the beam and scales are perfectly true, that is if the length of the beam on each side of the centre, or axis on which it turns, is exactly the same, and if the ends of the beam, and also the scales attached to them, are of exactly the same weight, and an equal weight or quantity of matter is put into each scale, the beam hangs in perfect equilibrium, that is, has no more tendency to descend at the one extremity than at the other. In this state of things, the centre of gravity of the beam, the scales, and the weights, is in the centre upon which the beam turns; and therefore the quantities on each side of this centre have the same gravitation, and if they were left to their own gravitation they would move over equal spaces in equal times till they met. But they are so perfectly trifling, as compared with the earth, that their gravitation towards each other is overcome or concealed by their gravitation toward the earth, and the tendency of both is towards its centre of gravity, and equally toward that centre in the case of their equality. When, however, there is a heavier weight placed in one scale of the balance than in the other, the centre of gravity of the whole is moved toward the heavier weight in the *same* proportion as that side of the balance is *heavier* than the other; or if it happens that the *balance* is untrue, by having a long arm and a short

one, the centre of gravity is thrown so far upon the long arm as to bring it exactly into the centre.

All these circumstances, and they are common to everybody's observation, tend to show that the gravitation towards any body, whether large or small, is always to the centre of the matter of that body, namely, that point within it which has an equal quantity of matter upon all sides of it in every possible direction. This has nothing to do with the presence or the absence of any second body that may controul the gravitation of the first, or of any third body which may controul the gravitation of either two towards each other, for it is the result of the very nature of gravitation; and the consequence of it is, that gravitating matter, indeed any matter unaffected by any other law than that of gravitation, would invariably form itself into a globe or sphere, the centre of which would be the centre of gravity, whether the quantity of matter were great or small; and if this were supported, the whole quantity of matter would be supported, whether the body were smaller than a mustard seed, or larger than the most voluminous or heavy body in the solar system.

We have, therefore, this very simple principle to guide us in our investigation of the mechanism of the heavens: the stability of every heavenly body is reduced to the stability of its centre of gravity,—and whatever law influences this centre of gravity must influence the entire body, whether that body is large or small; and thus the balancing of the solar system, or of any other system of bodies moving in free space, and sustained by *balancing forces*, is reduced to the sustaining or *balancing of* mere points.

The other branch of the law of gravitation fol

lows almost immediately from this,—namely, the law according to which the gravitating influence of bodies upon each other vary in proportion to the distances which they are apart. The tendency is to a centre, or single point; and we may suppose it to be exerted in straight lines diverging from that point in all directions; and those lines may be taken as an expression for the gravitating energy. They originate at the centre of gravity; and consequently, though their number is an indefinite one in every case, and not expressible by common arithmetic, it cannot be increased at any distance from the centre. That is to say, the gravitating influence of the earth is in its absolute amount exactly the same at the centre of the earth, which is a mere point, at the circumference of the earth, which is a spherical body, nearly eight thousand miles in diameter, and at any spherical distance surrounding the earth, which we can imagine, even though like the apparent concave of the starry heavens this distance should be too great for human measurement.

In order, therefore, to ascertain the law according to which the gravitating influence of the same body must vary at different distances from its centre, the influence of the body, being dependent on its quantity of matter, and proportional to and measurable by it, must be the same, taken on the whole, at all distances from its centre; and therefore, at different distances, it must be dispersed over spaces proportionable to those distances. Now the simplest mode of viewing those spaces is as the *surfaces* of spheres, the radii of which are the *distances*; and as the surfaces of spheres are in *proportion to* the squares of their radii, just as all *other surfaces* are in proportion to the squares of

lines equally related to them, it follows that, at different distances from the centre of gravity, the gravitating influence must be distributed over spaces proportional to the squares of those distances; or, in other words, that the influence of gravitation from one body, as telling upon the bulk or volume of another body, must diminish as the square of the distance. This is technically and very properly expressed by saying that the gravitating influence of any body upon another is inversely as the square of the distance between the centres of gravity of the two bodies, at the same time that it remains in each directly as the quantity of matter. Equal bodies at equal distances are of course equally influenced by the gravitation of any third body, and exert equal influence upon it; but because the gravitating influence as depending on the quantity of matter diminishes simply as the quantity of matter is diminished, while the same influence as depending on the distance diminishes as the square of the distance, it follows that at double the distance a body containing four times the quantity of matter will be required, in order to exert an equal gravitating influence, at three times the distance a body containing nine times the quantity of matter will be required, at four times the distance, one containing sixteen times the quantity of matterwill be necessary, and so on for all other distances, the quantity of matter in the body, supposing its influence to be always the same, requiring to be increased in the proportion of the square of the distance.

This follows immediately from the fact of gravitation being a central force, or referrible to the

centre of gravity of whatever body exerts it. It forms the other branch of the law of gravitation; and, therefore, we are enabled to enunciate the whole of that law in the following words:—The gravitating influence of bodies upon each other is directly as their quantities of matter, and inversely as the squares of their distances; and, therefore, in estimating the forces which sustain the planets in their orbits, we must carefully bear in mind both parts of this law.

Bearing this in mind, it is not difficult to see what must be the influence of any of the heavenly bodies upon another, or how it varies with the different distances. It is always directly as the quantity of matter in the body, and inversely as the square of the distance which they are apart from each other. It is of no consequence whether we refer the product or expression for the influence of this gravitation to the one body or to the other; for whatever may be the quantities of matter in the bodies, or their distances from each other, it is in all cases exactly mutual and reciprocal between them. This necessarily gives the larger body that power over the smaller one to which we have already alluded; and if there were no counteracting force they would approach each other by the smaller one moving toward the greater with more velocity than the greater moved toward the smaller.

Gravitation, as we have now explained the law of its operation, both with regard to the quantity of matter, or masses of bodies, and with regard to their distances from each other, is the principle of stability in the solar system; and if, as we may *naturally* enough suppose, there are similar systems

in other parts of the boundless regions of space, we may naturally, indeed necessarily conclude, that this also is the law of their stability.

This law of gravitation is not only the most general, but it is the most important law which we meet with in the whole range of the creation. It is not altered in a single iota by the kind or quality of matter. That matter may be as light as air or as hydrogen gas, rarefied by the seven-fold heat of a furnace, more intense than any volcano that ever raged near the earth's surface, or more intense than any of those which are sufficient to upheave continents from the depths of the sea, and turn mountain tops into ocean beds; or it may be as dense as platinum, or even as a substance a thousand times specifically heavier than platinum, and according as the specific gravity may vary, it may extend over millions of miles, or only over a single solid inch; but still there is no departure from the law of gravitation; for that remains perfectly true to the quantity of matter, and if it is free to act, that action is constantly in the inverse ratio of the square of the distance. So also it matters not under what distinctive class we know and describe the portion of matter. It may be living or it may be dead. If living it may be a portion of the human body, or of any animal or vegetable; if dead it may be an organic remain, a stone, a metal, or any of the other diversities of kind which we meet with in the mineral kingdom; and it may exist as a solid, as a liquid, or as a gas; but still under all these modifications this gravitation never quits it, and never changes one jot in its original intensity.

No doubt the different influence which the same body exerts at different distances, by decreasing as

the squares of those distances, confines the influence of any one body upon another, to any sensible extent, within limits which, as compared with the regions of space to which we can imagine no boundary, are comparatively narrow. But, even at the remotest distance which can be imagined, the gravitating influence of one body upon another never ceases altogether. It is constant to the quantity of matter; and though the other element diminishes as the square of the distance, yet as the reciprocal of this square never can become nothing unless the distance should extend to infinitude, there must always be a positive expression or product between this and the quantity of matter in the body; and therefore, within a finite creation, all the worlds and systems which can by possibility exist, must have a mutual influence upon each other, how slender and imperceptible by our senses soever that influence may be at very remote distances. This is a very beautiful part of the system of creation, because it links together in one bond of unity the whole of the works of God, how widely soever we may suppose them to be separated from each other; and if there is a general law of this extensive nature running through the whole of the world, and unaffected by the particular character of any one of those works, it gives us a more exalted idea of the Author than we could obtain by any other means, when we discover that the primary and simple law of His material creation, which is but one part of His works, extends so nearly to infinitude.

The antagonist principle which maintains the *balance* of the planetary system, and, as we may *suppose*, all the systems throughout the regions of

space against this universal gravitation, and between which and this the whole is sustained, and the motions and operations of every world, and of all its inhabitants carried on, is equally simple—it is merely motion; and motion which we can no more suppose to be self-originated by any of the bodies which possess it, than we can suppose gravitating matter and the law of gravitation to be self-originated. It is unquestionably as much a work of the Creator as the other; and though not a material work, it is one of a higher class, as being that by which all material nature is sustained.

In the planetary system, this motion, considered in itself, is exceedingly simple, though, from the gravitating influence of the planets upon each other, the results are not a little complicated. Each planet revolves round the centre of gravity of the whole system, situated as we have already remarked within the volume of the sun, though shifting a little from the centre of that volume according to the varying position of the planets; but the stability of the system requires that not one of those revolving bodies should perform its revolution in a perfect circle. Indeed, their doing so would be quite incompatible with that law of gravitation which we have endeavoured to explain. For as the balancing requires that there should be a constant proportion between the rate of motion in every planet, and its distance from the centre of gravity in the sun, no two of the planets can preserve the same distance from each other permanently, or even for any measurable length of time; but they must all be nearer to each other at some times, and farther apart at others. As their distance from each other increases, their influence upon each

other must diminish in proportion to the square of the increased distance compared with the shorter one. So also, from the differences of their angular positions with regard to the sun, the influence of one planet upon another must sometimes tend to increase the solar influence, and sometimes to diminish it. Thus for instance, as the earth is farther from the sun than Venus is, the mutual influence between the earth and Venus must be greater when both these planets are in the same straight line with the sun; and both on the same side of it, than at any other time; and while the attractive influence of Venus tends to pull the earth nearer to the sun, the attractive influence of the earth must tend to pull Venus in the other direction. So also, if the one planet is in advance of the other, it must tend to pull it forward, while the one which is in the rear must tend to pull the advanced one back. To what extent this may be done in any case is a matter for calculation, depending on the planets, their distances from each other, and their rates of motion at the time; and our object is not to enter on those calculations which involve the details of astronomy, but to state the general principles. It is perfectly evident, however, that, in consequence of those mutual disturbances, no planet can move in an orbit perfectly circular.

These mutual disturbances of the planets would be much greater in regard to the direct distance of each planet from the sun, if the paths or orbits lay all in the same plane. They do not deviate greatly from each other in this respect, but the planes of no two of them exactly coincide with each other, in consequence of which it rarely happens that the sun and any two planets are exactly in the same

straight line. By this means, the disturbance is resolved into two parts, one of which tends to draw the planet inwards or outwards from what would be its orbit if undisturbed, and the other tends to draw it upwards or downwards. These, in so far, counteract or diminish each other, and as every disturbance is attended either with an acceleration or a retardation of the disturbed planet, this also tends to lessen the ultimate effect of the disturbance. If the planet is retarded, the sun is thereby enabled to lay more powerful hold on it, and thus bring it a little nearer; and if it is accelerated, the sun has a little less influence upon it, and it escapes to a rather greater distance. The more remote planets, as being the larger ones, and also having the slowest rate of angular motion, necessarily exercise a greater retarding effect upon the nearer, smaller, and more swiftly moving planets, than these exert upon them. The difference is exceedingly trifling, and does not amount to a measurable quantity till after the lapse of a very long period of time; but still there is some small effect produced in this way, and it is probable that the orbit and annual period of the earth, for instance, are an exceedingly small fraction shorter now than they were thousands of years ago.

The orbits of all the planets are ellipses, or ovals, that is, curves described upon two centres, both situated in the longest diameter or measure through the ellipse, which diameter is called the major axis of the orbit, and is the most permanent element in it. The centres of such a curve are called the foci; and the one in which the sun is situated is called *the upper focus.* Half the distance between the *foci is called the* eccentricity of the orbit, because *it is the distance* which each of the centres of th

ellipse is from what would have been the single centre, if the orbit had been a circle having the major axis for its diameter. Of course, when the planet is at the upper extremity of the major axis, it is nearer the sun by the eccentricity than when it is at the mean distance, and nearer by twice the eccentricity than when it is at the lower extremity of the principal axis. Those extremities are called the apsides, or points of no deviation, because, at the instant when the planet is in either of them, its tendency for the moment, and without regard to what has happened before, is to move in a circle whose radius or distance from the circumference to the centre is equal to the distance which the planet then is from the sun; and when the planet is exactly mid-way between those apsides, in either half of the orbit, it is at its mean distance from the sun. This mean distance is equal to half the major axis; and the momentary rate of motion, without any reference to what has happened before, is that with which the planet would revolve in a perfect circle having the mean distance for its radius. The upper apsis is called the perihelion, or round the circle; and the lower apsis, the aphelion, or away from the sun. The motion of the planet in the first of these is more rapid than the mean motion, because its distance is less than the mean distance; and its motion in the aphelion is slower than the mean motion, because its distance there is greater than the mean distance. The motion of the planet is thus not uniform; for, from the perihelion down to the aphelion, it is continually getting slower; and from the aphelion up to the perihelion it is continually getting quicker. The difference is not great, because the orbits do not differ very much from circles, but still it is sufficient to maintain the

stability of the planet amid all the disturbances of the other planets.

Distance from the sun, and time of revolution, are not quantities of the same kind; and therefore the one of them cannot be expressed in terms of the other, though they are reciprocally the measures of each other. This will be readily understood by any one who reflects, that though it is absurd to speak of the number of miles that would make an hour, or the number of hours that would make a mile; yet that when the rate at which any thing moves is once estimated at so much in a certain time, the motion of that thing estimated in time becomes an accurate measure of the distance over which it passes, and the motion estimated in distance becomes an accurate measure of the time necessary to pass over that distance. In comparing the rate of a planet moving in its orbit with the absolute length of that orbit, or with the length of its diameters, which are the elements by means whereof the length of the orbit is determined, we cannot, therefore, apply the one directly as a measure of the other, and say that, because the orbit measures a given number of miles, the planet must perform a revolution in it in a given number of hours; but as the momentum, or tendency to move onward in a straight line, which the planet possesses, is not a force diverging from a centre, and therefore diminishing as the squares of the distance from that centre, and as the attractive force of the sun, by which the planet is retained in its orbit, is a force diverging from a centre, and therefore diminishing as the squares of the distances, it necessarily *follows, that* in two different planets, or in *the same planet* at two different distances from the

sun, the squares of the periodic time must be proportional to the cubes of the mean distances,—that is, the cube of the time must diminish as the square of the distance increases. The distance and the time must both be determined by actual observation, because as we have said they are not quantities of the same kind, they can have no proportion, and neither of them singly can be of the smallest use in determining the other one. When, however, we have ascertained the mean distance and the time of the revolution of one planet, and can find either the time or the distance of another planet, we have data enough for finding its other element, and this has been done with regard to all the planets by actual observation, by which means the law, as it affects the whole of them, has been shown to agree perfectly with the facts, and therefore to be quite true.

Upon the principle of this law, no planet revolving in an ellipse can have a uniform motion, but must move faster in those parts of its orbit in which it is nearer to the sun than it does in the more remote ones. Bodies in motion acquire a momentum, or tendency to move, in proportion to their velocity; and as every effect in the operation of matter requires some time for its production, and a motive effect, or active effect of any kind in matter, also requires some time for its destruction, we have a solution of all the changes of motion of a planet in an elliptic orbit, which perfectly explains the phenomena. Let us take the planet at starting at the perihelion of its orbit (for, as we know not in *what part* of the orbit the planet was at the moment *of its creation*, we may as well take it in one point as *in another*), and let us consider the circumstances

under which it arrived there, and also those under which it is momentarily placed there. From the aphelion it has been gradually approaching nearer to the sun, and, according to the constant proportion which exists between the distance and the rate of motion, its progress must have been gradually accelerating during its passage from the aphelion. Consequently it must have arrived at the perihelion with an accumulated motion upon it, which cannot be destroyed until some time has elapsed: but at this point, it moves as if in a circle whose radius is the perihelion distance, and is moving within the circumference of this circle with a greater velocity than is consistent with permanent motion in the circle, and therefore it gets without. Getting without it is under the law of a greater distance, and its motion begins to retard, and so continues down to the aphelion, where it arrives with a retarded motion accumulated upon it. It is there in a circle answering to the perihelion distance, and with a retarded motion, which enables the sun to bring it within the circle, and the instant that this is done, its motion again begins to accelerate, and it ascends to the perihelion as before.

Such are a few points in the outline of the system and phenomena of the heavens, the most extensive and the most glorious works of God,—works which lead us directly to the most reverential adoration, without any excitement of words; and therefore with this notice of them we close our brief survey of the material creation.

THE END.

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